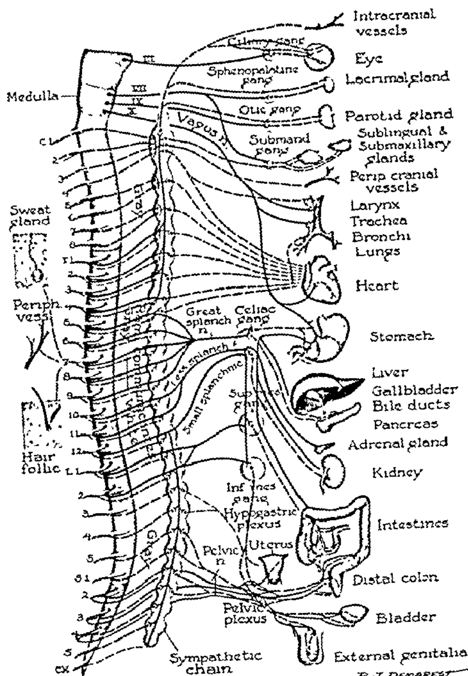


Diagram of the autonomic nervous system. Red lines indicate thoracicolumbar, blue lines craniosacral outflow; solid lines preganglionic, broken lines postganglionic fibers.

CALLANDER'S

Surgical Anatomy

BY

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This Book is Dedicated to the Authors' Teachers

FREDERIC THOMAS LEWIS, M.D.

Late James Stillman Professor of Comparative Anatomy
Harvard Medical School

and

FREDERICK AMASA COLLER M.D., LL.D.

Professor of Surgery, Emeritus
University of Michigan Medical School

In admiration of their scholarship, pedagogic judgment and dedication to the kindly guidance of aspirants in the fields of anatomy and surgery

Preface to the Fourth Edition

SOBER EVALUATION of fifty published reviews of the third edition of the *Surgical Anatomy* has led inescapably to the conclusion that the pattern of presentation therein followed met with approval. As a consequence, the authors have retained the fundamental architecture, while modifying the constituent elements wherever amplified knowledge of structure or improved technical procedure called for closer adaptation to present-day use of their book. Again, the rationale, rather than its detailed steps, of surgery has been stressed; techniques change, but parts of the human body merely vary in the population, between predictable limits and by types in percentage occurrence determinable by laboratory and clinical study.

For assistance in revising parts of the volume, the authors are chiefly indebted to Dr. George H. Gardner, Dr. John W. Huffman, Dr. Theodore R. Hudson, Dr. William J. Schnute, Dr. Vincent J. O'Conor, Dr. George E. Shambaugh, Jr., Dr. Nicholas Wetzel, Dr. Chester B. McVay, Dr. William A. Mann, Dr. Edward A. Boyden and Dr. Amos R. Koontz.

Textbooks and journals have been examined critically, in a down-to-date appraisal of their chirurgico-anatomical content serviceable to the current undertaking. To the authors of these books and many journal articles the present writers are deeply grateful for permission to reproduce figures of exceptional value; in many instances they have supplied original drawings or engravings. Additionally, Dr. Edward A. Boyden, generously supplied a full account of the anatomy and physiology of the gallbladder. Dr. Nicholas Wetzel composed the new text on the applied anatomy of the scalp, cranium, brain and meninges.

Equal gratitude is owing, and is hereby expressed, to the editors of the journals in which the original articles appeared.

In a number of instances the use of illustrations in the *Atlas of Human Anatomy* proved to be accordant with the objectives set for the *Surgical Anatomy*. Several of these, depicting entire dissection areas, have been used in unaltered or in slightly modified form as frontispieces for the parts, or as pictures interpolated in a regular series in the body of the text; others, recording variations in the form and attachments of muscles, in the origin and distribution of arteries, in the anastomosis and termination of veins and in the course and relations of nerves, have been redrawn with augmented supporting records. For collaborative aid in collecting both the original and the sequential sets of data, the senior author is again in the debt of his faithfully energetic graduate students in Gross Anatomy. The new drawings were prepared by Mary Dixon, Jean McConnell and Lucille Cassell Innes; they are additive to others prepared earlier by the same artists, and by Tom Jones, Willard C. Shepard, W. Branks Stewart and Rosamond Howland.

A borrowed illustration, in many instances, is but one in a writer's ample series, from either a textbook or journal. In order to do full credit to the source, and in order to provide the reader with a ready guide to the periodical or book, the present authors have recorded the origin in the form of a bibliographic citation.

Finally, a gracious and grateful bow is due the publishers. Matching the encouragement given in preparation of the third edition, the Saunders Company maintained a continuum of guiding interest toward completion of a textbook which, in the authors' judgment, would fit the professional needs of the advanced student, the resident and the practitioner.

BARRY J. ANSON
WALTER G. MADDOCK



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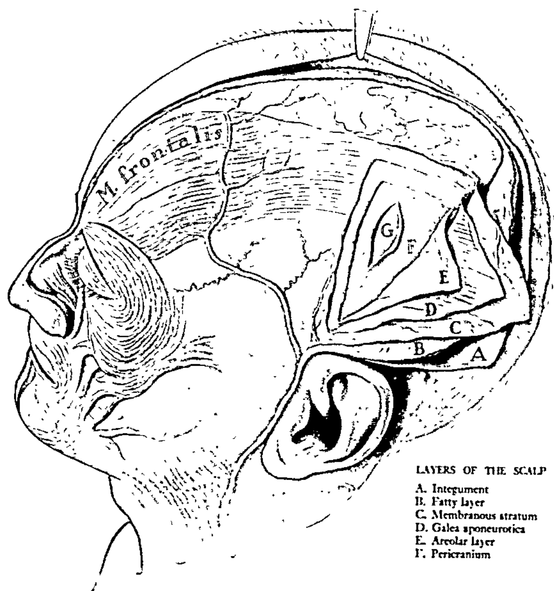
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PART I

The Head



CHAPTER 1

Scalp, Cranium, Meninges and Brain

Extracranial Soft Parts

The scalp is of particular surgical interest not only because it serves as a covering of the skull, but also because it is a frequent site of many skin lesions. Scalp lacerations are the most common type of head injury requiring surgical care. If a scalp laceration receives proper treatment, it will heal nicely; if not, many dire consequences may ensue, and these may include osteomyelitis of the skull with or without intracranial extension. Various superficial cysts have a decided predilection for the scalp, and vascular tumors of the scalp may communicate with the intracranial sinuses. The scalp by itself forms a thick cushioning layer which is adequate protection for the intracranial contents against all but the most severe and direct trauma.

The soft parts over the skull consist of five layers: the skin; the subcutaneous tissue; the epicranius (occipitofrontalis) muscle and its galeal aponeurosis; a lax layer of subaponeurotic connective tissue; the pericranium or outer periosteum of the skull (Frontispiece and Fig. 1). The hair should also be considered an integral portion of the scalp and of surgical importance, since its removal is essential for proper cleansing of the scalp or of scalp lacerations. From a surgical standpoint the first three strata are regarded as forming a single layer, the scalp proper, since they are connected intimately and are not readily separated.

SKIN. The skin of the scalp is thick, particularly in the occipital region, and is attached by tough fibrous septa to the underlying galea (epicranial aponeurosis). It has an abundant arterial and lymphatic supply; the arteries are derived from the vessels in the subcutaneous tissue. Because of this abundant arterial supply scalp lacerations heal well. Within the skin are numerous sweat and sebaceous glands which, under certain circumstances, may develop into cysts. These cysts (wens) are contained within the true skin; they do not invade the subcutaneous tissue and hence move with the scalp.

SUBCUTANEOUS TISSUE. The subcutaneous tissue is dense and tough because of the presence of numerous short fibrous septa which also enclose small fat lobules and form an in-

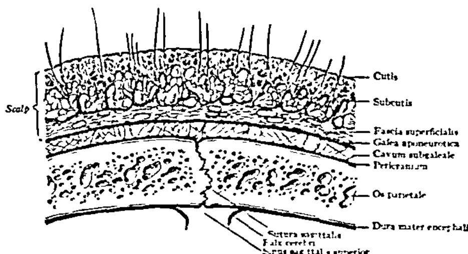


Fig. 1. FRONTAL SECTION THROUGH THE EXTRACRANIAL SOFT PARTS AND THE PARIETAL BONES.

elastic layer carrying the blood vessels. The blood vessels embedded in this unyielding tissue do not contract fully; they bleed freely when divided. The vessels of the scalp are numerous and amply anastomotic; hence large scalp flaps with relatively small pedicles may survive, and large lacerations heal surprisingly well. The abundant blood supply also leads to alarming hemorrhage; and until specific methods of control were developed by Cushing and others mere incision of the scalp was a procedure attended with much hemorrhage. Simple compression of the skin adjacent to a scalp wound between the finger tips and the underlying skull will, however, control the most severe hemorrhage.

Superficial infections are prone to remain localized in the subcutaneous tissue because of the fibrous septa. The amount of subcutaneous fat is relatively constant, varying little in emaciation or obesity, but seemingly decreasing with advancing age.

Epicranius (Occipitofrontalis) Muscle and Its Galeal (Epicranial) Aponeurosis. The paired, double-bellied epicranius muscles and their intervening aponeuroses are attached posteriorly to the external occipital protuberance and to the superior nuchal (curved) line of the occipital bone. The muscles have no well defined lateral margins. Anteriorly, they are attached through the frontal bellies mainly to the superciliary ridges and subcutaneous tissue over the eyebrows and nose and to the orbicularis oculi muscles. From a surgical standpoint the galea is the most important layer of the scalp in that it is the only layer of any strength, and hence the one upon which the surgeon must depend to maintain the integrity of the sutured wound. Harvey Cushing is purported to have said that he would be satisfied to be remembered as being the one who first sutured the galea, and to have his headstone so marked. Because the vessels of the scalp lie superficial to the galea and are impossible to ligate, bleeding therefrom may be controlled by application of hemostatic forceps to the galea, thus allowing the weight of the forceps to compress the bleeding vessel. If bone is removed, as is done in many neurosurgical procedures, a carefully sutured galea will prevent disruption of the scalp incision should any swelling of the intracranial contents occur. Early failure to suture the galea usually led to cerebral fungus (necrotic infected brain protruding from the wound), to meningitis and to death.

Subepicranial Connective Tissue Space. The subepicranial space lies between the epicranius muscle and the pericranium. This potential space is traversed by small arteries and by the important emissary veins which connect the intracranial venous sinuses with the superficial veins of the scalp. Subepicranial abscess is likely to occur when infection, following a galeal laceration, fails to find ready exit; then, spreading in all directions, the abscess elevates emissary veins, with septic emboli that pass into the dural sinuses. Hence the subepicranial space may be called the "danger zone" of the scalp.

Pericranium. The pericranium is the outer periosteum of the skull. In the fetal skull the membranous spaces, or fontanels, lying between the undeveloped cranial bones, are bridged by the pericranium externally and by the dura mater internally. When these fontanels are obliterated, the sutural membrane of connective tissue connects the pericranium with the dura mater across the suture line. This circumstance explains the ease with which the pericranium may be stripped from the bones, except at the suture lines. When the bones fuse, the suture lines are obliterated, and the pericranium stretches from one bone to the other with no strong sutural attachment. Cephalhematoma, an accumulation of blood, occurs in the subpericranial space and is characteristically found in the newborn infant, and may be limited to one or both of the parietal bones. Subpericranial abscesses are comparatively rare.

The pericranium differs from periosteum elsewhere in that it nourishes the underlying bone to only a limited degree and has but little bone-forming power. Stripping the scalp and the pericranium does not cause subsequent necrosis of the underlying bone; however, some demineralization may take place.

Vessels and Nerves. Aside from the small frontal and supraorbital branches of the ophthalmic artery, the arterial supply of the scalp is derived from the superficial temporal, posterior auricular, and occipital branches of the external carotid artery (Fig. 2). These vessels run in the subcutaneous fat from the periphery toward the vertex and anastomose freely across the midline with one another and with the

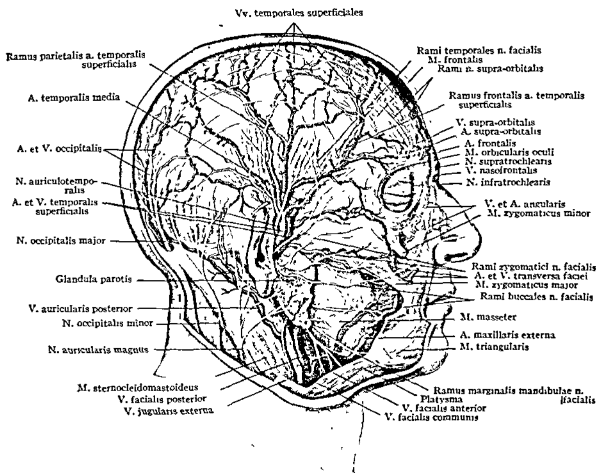


Fig. 2. BLOOD VESSELS AND NERVES OF THE FACE AND SCALP.

above-mentioned branches of the ophthalmic artery. In thrombosis of the internal carotid artery a flow of blood from the external carotid artery through the ophthalmic artery frequently occurs. Because of the adequate blood supply, necrosis of scalp flaps is infrequent.

An inflammation of the superficial temporal artery, termed "temporal arteritis," occurs occasionally and may be the cause of headache. Relief may be secured by excision of the involved segment of vessel. Cirsoid aneurysms, a peculiar form of vascular growth, are also occasionally observed along the source of the superficial temporal or occipital arteries. The aneurysms are composed of groups of large, tortuous and pulsating vessels which form an irregularly circumscribed bluish-red swelling beneath the skin. Arteriovenous fistula may result from trauma to the scalp.

The frontal, parietal and occipital veins follow the arteries as anterior, lateral and posterior venous stems and empty into the external jugular vein. The frontal and supraorbital veins unite at the median angle of the eye and communicate there with the angular vein (the beginning of the facial vein). The supraorbital vein has an anterior diploic branch and a branch which communicates through the orbit with the ophthalmic vein, the latter being a tributary to the cavernous sinus (Fig. 13). The lateral and posterior veins of the scalp drain mainly into the external jugular. However, some pass by way of the diploic veins into the superior sagittal (longitudinal) sinus. The mastoid and condyloid emissary veins drain into the transverse (lateral) sinus; the supraorbital veins drain into the ophthalmic vein and thence into the cavernous sinus (Fig. 8). From these main channels profuse hemorrhage may occur during craniotomy, and by way of these channels, and others less conspicuous, infection may spread from the scalp and face to the interior of the skull and lead to sinus thrombosis and meningitis. Thus a seemingly trivial scalp infection or a contaminated laceration may lead to serious intracranial disease.

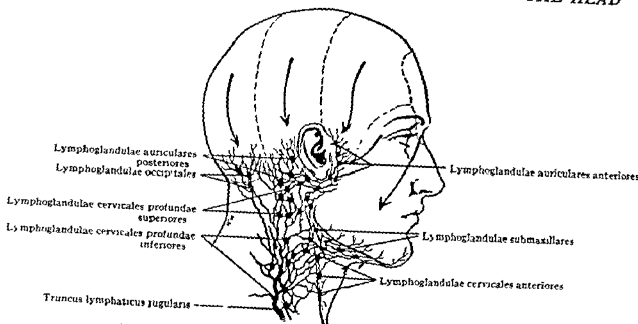


Fig. 3. REGIONAL LYMPH DRAINAGE FROM THE SCALP AND FACE.

The lymph vessels of the scalp drain downward from the occipital region to the occipital glands; from the parietal and temporal regions to the preauricular and postauricular glands; and from the frontal and frontoparietal regions to the submaxillary glands (Fig. 3).

The nerves of the scalp, with the exception of the facial supply to the epicranius (frontalis) muscle, are purely sensory (Fig. 2). It is possible for the neurological surgeon to use the injection of local anesthetic agents alone for many operations on the head and skull. The supratrochlear, supraorbital and auriculotemporal nerves are branches of the trigeminal nerve. The great auricular, the major and lesser occipital are of spinal origin. Any of these nerves may be affected by neuralgia, the supraorbital nerve by trigeminal neuralgia of its ophthalmic division, while pain in the distribution of the occipital nerves may be due to an osteoarthritis of the cervical spine which compresses these nerves as they pass through the intervertebral foramina.

Cranium in General

LANDMARKS. The cranial vault, superciliary arches, orbital margins and angular processes of the cranium are palpable (Figs. 4, 6). The zygomaticarch, supramastoid crest, suprameatal spine and mastoid process are easily located (Fig. 7). The external occipital protuberance s sometimes quite prominent (Fig. 5).

In times past much effort was expended in attempts not only to correlate cranial configuration with cerebral development and function (phrenology), but also to enable the surgeon to expose specific areas of the cortex through small incisions. The latter procedure is not desirable and is no longer necessary. Furthermore, it has been found that there exists such variability in the bony structure of the skull that accurate localization of various neural structures is impossible.

DEVELOPMENT OF THE CRANIUM. It is necessary to review the development of the skull in order to explain the existence of the fontanels, which are important in obstetrical diagnosis, and to account for the various congenital anomalies of the skull which have surgical significance.

The bones of the cranial vault develop as the result of ossification of a membranous matrix; because transformation into bone is not complete at birth, areas of unossified membrane are present at birth. The area of confluence of the frontal, interparietal (sagittal) and coronal sutures is diamond-shaped and is called the anterior fontanel; the triangular posterior (occipital) fontanel is formed by the junction of the sagittal and lambdoid sutures. The apex of the posterior fontanel extends between the parietal bones, while the two sides pass laterally into the lambdoid sutures. These two fontanels are of great aid to the obstetrician in determining the position of the fetal head during labor,

since they may be felt by an examining finger placed in the rectum.

Normally the membranous fontanels ossify during the first year of life. During the period in which they remain open a rough approximation of the state of intracranial pressure may be obtained by palpation of the fontanels. By inserting a suitable cannula at the lateral edge of the anterior fontanel the subdural space, or even the ventricle, may be entered for diagnostic or therapeutic purposes without the necessity of drilling a hole through the skull.

The child's skull normally increases in size until about the age of twelve. Two factors are concerned: the growth of the brain and the accommodating increase in size of the skull through growth at the various suture lines. The size of the child's skull, measured by its circumference, has been carefully studied, and tables and graphs of growth rates are available. With this information the physician is able to determine, in any particular case, whether the rate of growth of the head is too great—as in hydrocephalus—or too little—as in the various forms of craniosynostosis. In the hydrocephalic child various disturbances of formation or absorption of the cerebrospinal fluid are present (see below). In craniosynostosis premature closure of the various fontanels and sutures takes place, and may lead to the constriction of the enclosed brain, or to the production of an abnormally shaped skull. Both these con-

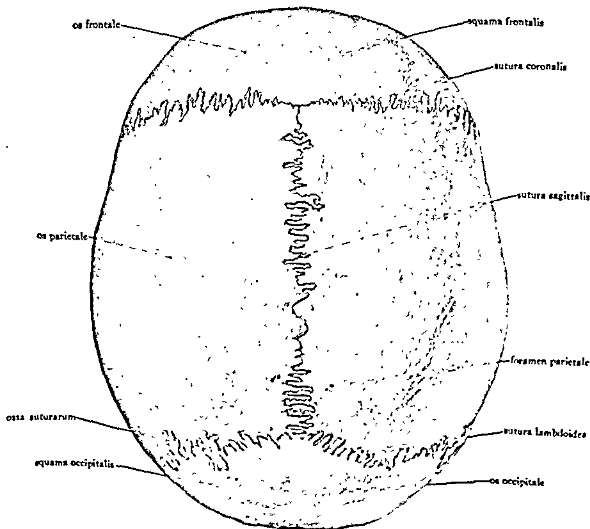


FIG. 4 SKULL, SUPERIOR VIEW.

(From Warren. Handbook of Anatomy, Harvard University Press, Cambridge.)

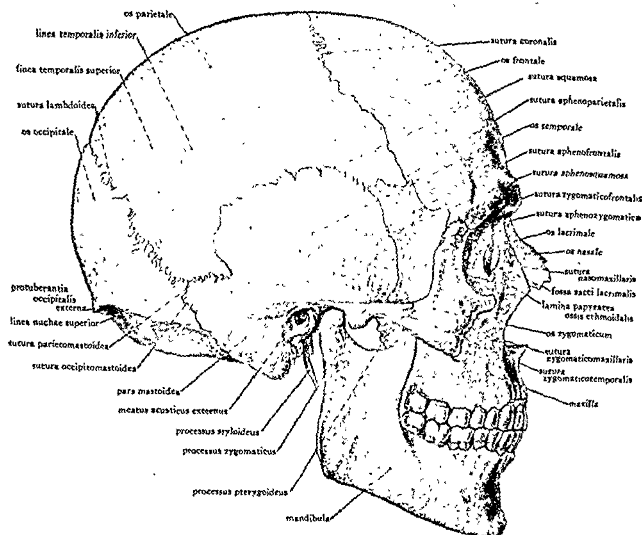


Fig. 5. SKULL, LATERAL VIEW.
(From Warren: Handbook of Anatomy, Harvard University Press, Cambridge.)

ditions are serious, not so far as they affect the skull, but rather because they may restrict the normal development of the cerebrum. Treatment of the various forms of craniostenosis is directed toward surgical excision of the various sutures and toward prevention of fusion. Tendency to fuse is strong; consequently the edges of the bone must be covered with a foreign material to prevent the bony plates from growing together again.

The bones of the skull are capable of undergoing great change in shape (molding) during birth; they are, therefore, pliable. As the bony centers grow in the membrane, an outer periosteum, or pericranial, and an inner, or dural, layer develop. With the laying down of bone, inner and outer dense deposits form about an intervening spongy diploic layer (Fig. 8). The amount of diploic bone varies. The bony channels of the diploic veins are easily seen in roentgenograms and can be mistaken for fractures.

From a mechanical or architectural standpoint the skull is a *complex structure. Its strength depends not so much on the thickness of the bone as on a combination of buttresses* and panels; these play an *important part in* determining the reaction of the *skull to trauma*. Because of these factors the site of fracture may be distant from the point of impact. In head injuries fracture of the skull by itself is of minor importance to the patient when compared to the accompanying damage to the brain (Figs. 9, 10). The skull may be literally shattered without injury to the brain or cranial nerves and without leakage of cerebrospinal fluid; owing to these circumstances, the consequences may be negligible. A more serious head injury

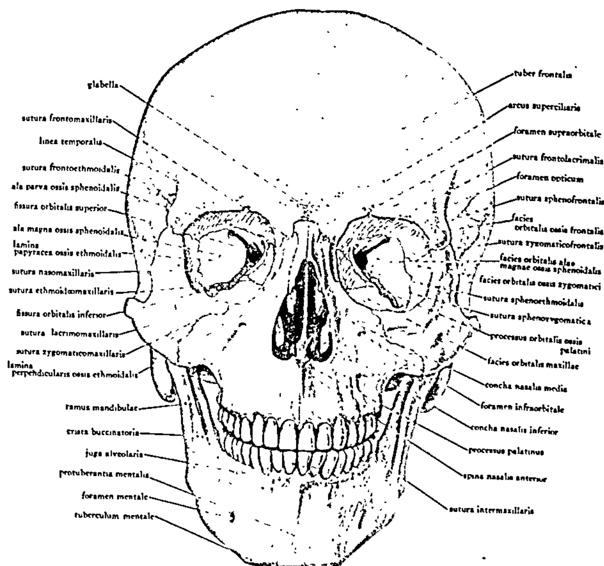


Fig. 6. SKULL, ANTERIOR VIEW.
(From Warren Handbook of Anatomy, Harvard University Press, Cambridge.)

may result from the intracranial contents being lacerated by the sharp edge of the petrous ridge of the temporal bone, the sphenoid ridge or by the cerebral falx or the cerebellar tentorium. There are, of course, instances in which the fracture is the contributing, not the important, factor in the injury. Among these may be mentioned the following: rupture of the middle meningeal artery, as a result of fracture of the temporal bone; fracture through the anterior cranial fossa which opens the cribriform plate into the nasal cavity, with resulting rhinorrhea; a fracture through the temporal bone which damages the facial nerve and leads to an otorrhea.

The bones of the skull may be affected by various forms of systemic disease. For example, in rickets, because of impaired calcium metabolism, the squamous (thin, scale-like) portions of the parietal and occipital bones become parchment-like and yield to touch. Excessive prominence of the parietal bosses is noted in some cases of congenital lues. Osteomyelitis of the skull may occur, usually from direct trauma, but at times from spread of infections of the sinuses, particularly the frontal.

The skull is frequently affected by metastatic tumors, less often by primary tumors of the bones of the skull itself. It may be indirectly affected by intracranial tumors, par-

sutura palatina mediana
fissura orbitalis inferior
sutura palatina transversa
pars horizontalis ossis palatini
facies temporalis ossis sphenoidalis
processus pyramidalis ossis temporalis
foramen lacerum
fissura sphenooccipitalis
fissura petrotympanica
fossula petrosa
foramen occipitale magnum
linea nuchae inferior
crista occipitalis externa
linea nuchae superior
protuberantia occipitalis externa
foramen palatinum majus
foramen palatinum minus
fossa pterygoidea
fissura sphenopetrosa
sutura sphenosquamosa
tuberculum articulare
fossa mandibularis
foramen caroticum externum
porus acusticus externus
processus styloideus ossis temporalis
foramen stylomastoideum
fossa jugularis
condylus occipitalis
foramen mastoideum

Fig. 7. SKULL, INFERIOR VIEW.
(From Warren: Handbook of Anatomy, Harvard University Press, Cambridge.)

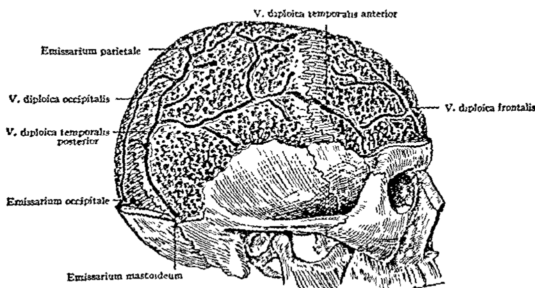


Fig. 8. VASCULAR CHANNELS IN THE DIPLOE.
The outer table of compact bone has been removed from the frontal, parietal and occipital bones.

ticularly the meningiomas. Tumors of meningeal type may cause localized overgrowth or destruction of the bones of the skull. These changes may be apparent on roentgenograms of the skull. A benign thickening of the frontal bones, known as hyperostosis frontalis interna, may also be seen on routine films and is of questionable significance. Paget's disease, of unknown origin, but somehow associated with bony metabolism, gives rise to a thickening of the cranial vault.

Platybasia or basilar impression is a condition, probably congenital in origin, in which the normal relations between the base of the skull, the cervical vertebra and the remainder of the skull are altered. It is associated with various other anomalies of the craniovertebral axis. Because of the attendant alteration in relations between the foramen magnum, the lower cranial nerves and the hind brain, various neurologic disturbances may arise. Some of these are alleviated by a surgical decompression. Patients with platybasia appear to have short necks; roentgenograms of the skull reveal a characteristic deformity, in which the first cervical vertebra appears to lie above the normal level of the foramen magnum and within the cranial cavity.

Various endocrine disorders may cause changes in the growth or conformation of the skull.

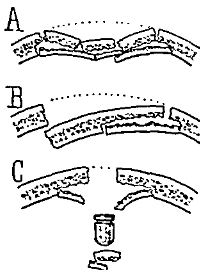


Fig. 9. DIAGRAMS OF FRAGMENT DISPLACEMENT IN COMMINUTED FRACTURE OF THE VAULT.

A, Fracture with central depression; *B*, fracture with peripheral depression; C, fracture with loss of bony substance. (Cushing)

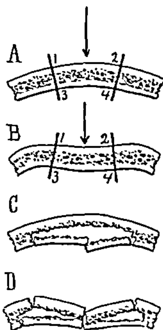


Fig. 10. DIAGRAMS ILLUSTRATING THE MECHANICAL PRINCIPLES OF BENDING FRACTURES.

In *A* and *B* the arrow indicates the direction of impact; points 3 and 4 are dragged apart until the tensile strength is overcome; *C* shows the possible effect on the inner table alone; *D* shows the possible effect on both tables. (Teevan.)

Tumors of the pituitary gland, particularly eosinophilic adenomas of the anterior lobe, produce gigantism in the young through overproduction of growth hormone. After puberty the changes are most notable in the enlargement of the hands and jaw, and in prominent supraorbital ridges. Tumors of the pituitary erode, or "balloon out," the sella turcica, the enlargement being evident on ordinary skull roentgenograms. These changes are most often seen in chromophobic adenomas of the anterior lobe; they are characterized by signs of hypopituitarism in contrast to the chromophilic tumors, which exhibit signs of hyperpituitarism.

The Meninges (Cranial Envelopes)

A thorough knowledge of the structure and relations of the cerebral membranes, their contained fluids, and the part they play in cranial and intracranial disease is of great importance. The brain is separated from its bony container by three superimposed envelopes: the dura mater, the arachnoid and the pia mater. These membranes form three intracranial spaces. Between the skull and the dural investment is the potential extradural space; separating the

dura mater from the arachnoid is a subdural space; and a *subarachnoid* space, containing the cerebrospinal fluid, is situated between the arachnoid and the pia mater. The first two of these spaces are only potential; they become real only when distended by blood or some other fluid. The most important relationships of these spaces are those which exist between them and their blood vessels.

THE DURA MATER, ITS VENOUS SINUSES AND THE MIDDLE MENINGEAL ARTERY

The Dura Mater. The dura mater is a relatively thick membrane of densely felted, collagenous tissue, which possesses only slight elasticity, and, on its outer surface, carries ramifications of the middle meningeal arteries. The dura may be split into two layers, and is actually bilaminar locally where it forms the great intracranial venous sinuses and encloses the semilunar ganglion.

The outer layer of the dura, which is the periosteum of the inner surface of the skull (Fig. 11), has limited power to form new bone. The strength of dural adhesion to the skull is variable, as is the thickness of the dura. Adhesion is particularly strong at the base, so that basilar fractures are frequently accompanied by dural tears and cerebrospinal fluid leakage into the nasal cavities or middle ear. In the newborn the attachment of the dura is strong at the margins of the bones because of the fusion of the bony membranes at these points. Hence in the child, extradural hemorrhage is usually limited to the inner surface of one bone. The dural sheath is more loosely attached in the parietal and occipital regions than in the frontal area. The dura is also somewhat thinner in the frontal regions than elsewhere.

Owing to its toughness and smooth inner surface, the dura furnishes excellent protection to the brain. A well sutured dural wound adheres but little to the underlying pia arachnoid, and heals well.

As mentioned above, the dura mater over the convexity of the hemispheres and elsewhere may be split or dissected into two layers; the outer stratum is analogous to the periosteum, whereas the inner layer constitutes the dura proper. The latter part is continuous with the dural envelope of the spinal cord, while the former corresponds to the periosteum of the vertebrae. The space between these two is real; it contains blood vessels and adipose tissue, and is known as the spinal epidural space.

At certain points the dura proper leaves the outer dura to form folds which project into the cranial cavity; these infoldings form partitions between parts of the brain, and contain the venous sinuses (Fig. 12). These folds are as follows: the falx of the cerebrum; the tentorium of the cerebellum; the cerebellar falx and the diaphragm of the sella turcica. These partitions, although permitting easy flow of cerebrospinal fluid in subjacent spaces, are strong enough to restrict shifting of the various parts of the brain.

The cerebral falx and the cerebellar tentorium are of surgical importance, since they may cause local cerebral injury by their unyielding

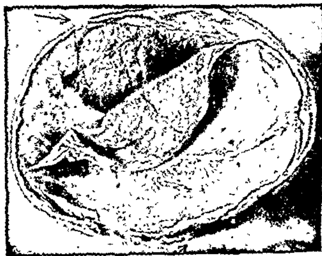


Fig. 11. Inner surface of the calvarium with the dura reflected, showing extradural hematoma. The clot is grooved by the meningeal artery, which has been torn in a linear fissure from the meridional fracture. (Cushing.)

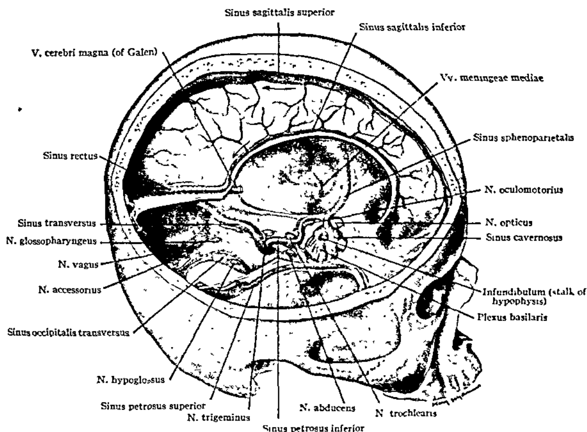


Fig. 12. RIGHT LATERAL HALF OF THE CRANIAL VAULT REMOVED TO SHOW THE TOPOGRAPHY OF THE DURAL SINUSES.

A segment is removed from the cerebellar tentorium to show the foramen magnum and the transverse sinus; arrows indicate the direction of venous flow.

surfaces and sharp edges. The cerebral peduncles are particularly vulnerable to damage from the edges of the tentorium; whereas the mesial surface of the frontal, parietal and occipital lobes may be pressed against the edges of the falx. The rigidity and strength of the dural folds are further illustrated by the resistance of the diaphragm of the sella turcica to the expansion of pituitary tumors. These neoplasms "balloon" or enlarge the bony sella long before the diaphragm gives way sufficiently to allow the tumor to expand into the cranial cavity.

Dural Venous Sinuses. These important structures are formed by a separation of the two dural layers at various points of the skull; they are the main channels for venous drainage of the brain (Fig. 12). The largest of these, the superior sagittal sinus, lies in the sagittal plane; increasing in size as it passes from the frontal region to the occipital, it empties into the torcular Herophili, or confluence of the sinuses. The *confluens sinuum* is situated approximately in the midline, and into it drain the superficial veins of the cerebral cortex, the straight sinus and the occipital sinus. The straight sinus receives blood from the deep cerebral venous system; the occipital sinus, although lying between the two cerebellar hemispheres posteriorly, receives no venous drainage from those structures. From the confluence of the sinuses two sigmoid sinuses pass laterally, to empty into the two internal jugular veins. The two sigmoid or transverse sinuses occupy folds in the cerebellar tentorium. These dural channels communicate with the superior and inferior petrosal sinuses, which communicate, in turn, with the cavernous sinus (Fig. 13).

Several large emissary veins traverse the skull in the parietal and mastoid regions; in draining the scalp, they offer direct communication between it and the lateral or transverse sinus (Figs. 12, 13). These vessels may be the source of alarming hemorrhage in operations which involve the removal of bone. Hemorrhage is severe in those instances in which the intracranial pressure, and consequently venous

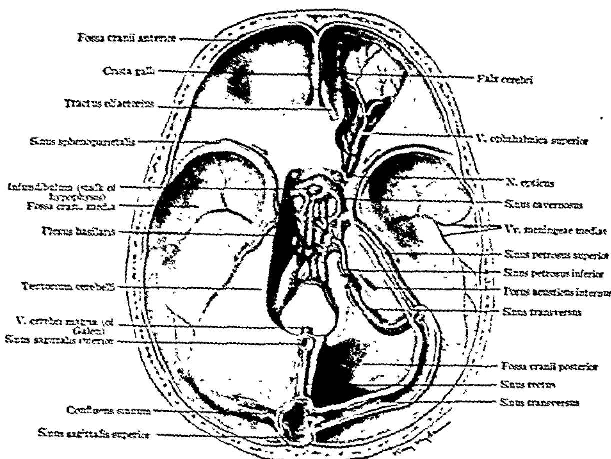


Fig. 13. SINUSES IN THE DURA VIEWED FROM ABOVE.
The cerebellar tentorium has been removed on the right.

pressure, is increased (as is often the case in removal of tumors in the posterior fossa).

At the sides of the body of the sphenoid bone lie the cavernous sinuses with their anterior and posterior intercavernous connections (Fig. 12). At the orbital fissure each sinus receives tributary ophthalmic veins, which are capable of transmitting infections from the orbit, and from the connecting angular veins of the face, to this particular sinus. At the apex of the petrous portion of the temporal bone the cavernous sinus terminates by emptying into the superior and inferior petrosal sinuses; they, in turn, drain into the internal jugular vein and transverse sinus. Several fairly large-sized veins also carry blood from the cerebellum to the superior petrosal sinus in the region of the trigeminal nerve, where the latter passes beneath the petrosal sinus. These veins may have considerable surgical significance in operations in this region. The cavernous sinus forms a cavity which is crossed by fibrous strands and contains in its walls the internal carotid artery, the oculomotor, trochlear and abducens nerves, and the ophthalmic division of the trigeminal nerve (Fig. 16).

Inferomedial to the cavernous sinus lies the sphenoidal sinus—a relationship which provides the possibility of a cavernous sinus thrombosis originating from a sphenoid sinusitis. The passage of the carotid artery through the cavernous sinus renders production of an arteriovenous fistula possible whenever the artery is injured, as in cases of basilar fracture through this area. These patients frequently note an intracranial bruit, which can also be heard by the physician upon attentive listening. Injection of the conjunctival vessels, followed by increasing proptosis of the involved eye, is noted as the vessels of the orbit become increasingly filled with arterial blood. Ligation of the carotid vessel involved will usually give the patient relief. Early recognition of the lesion is important, since progression of the proptosis may lead to eventual loss of the eye.

THE MIDDLE MENINGEAL ARTERY. The middle meningeal artery is the terminal branch of the external carotid (Fig. 15); its immediate

source is the internal maxillary. The artery enters the cranial cavity through the foramen spinosum, situated at the most inferior portion of the middle cranial fossa. It is the chief source of blood supply to the dura mater; it is of great surgical importance because of the extensive hemorrhage which occurs when it is torn.

The middle meningeal passes laterally in the dura mater of the floor of the middle cranial fossa for a distance of 2 to 3 cm., and then typically divides into two branches. In approximately one-third of a large series of anatomical dissections the anterior and posterior branches were of equal caliber; in 40 per cent the anterior branch was by far the larger; and in the remainder a number of variations occurred. The anterior branch passes superiorly along the greater wing of the sphenoid and, because it may be more or less enclosed in a bony canal, is clearly seen on lateral roentgenograms of the skull. The middle meningeal artery may at times lie on the surface of the dura mater; more often it is lodged in the substance of the dura and, as a consequence, is inseparable from that layer. The posterior branch passes over the parietal lobe. Either or both of these vessels may be injured in fractures of the skull, or merely by being avulsed from the skull. Under either circumstance the result is arterial bleeding into the extradural space (Fig. 14).

Although much has been written in the past about various inflammatory diseases of the

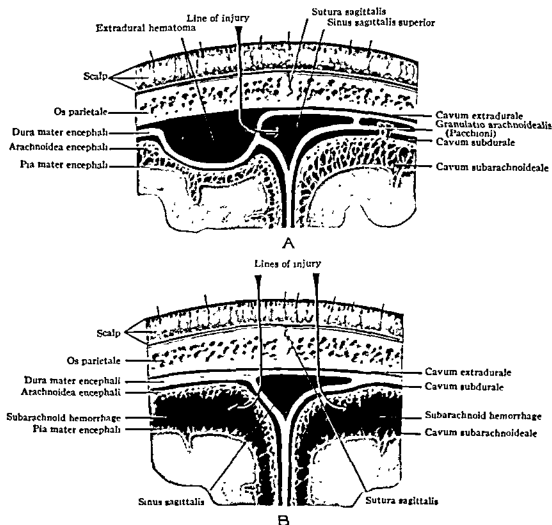


Fig. 14. DIAGRAMMATIC FRONTAL SECTIONS THROUGH THE SUPERIOR SAGITTAL SINUS TO ILLUSTRATE THE MECHANISM OF EXTRADURAL AND SUBARACHNOID HEMORRHAGES.

A, Laceration of the superior sagittal sinus producing an extradural hematoma. *B*, Laceration of the superior sagittal sinus producing an extravasation of blood into the subarachnoid space.

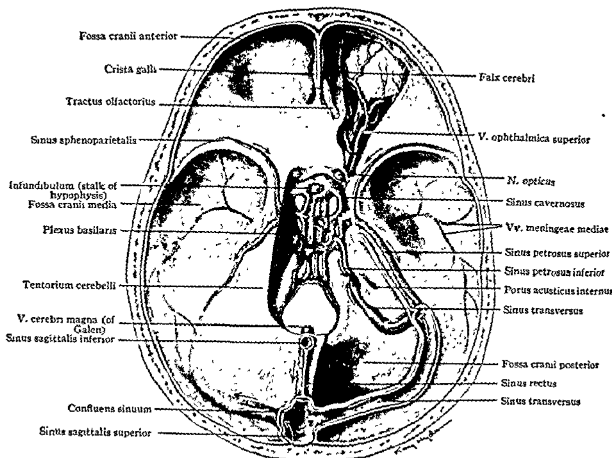


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THE MIDDLE MENINGEAL ARTERY. The middle meningeal artery is the terminal branch of the external carotid (Fig. 15); its immediate

sinus thrombosis has decreased greatly since the advent of antibiotics.

THE ARACHNOID, PIA MATER, SUBARACHNOID SPACE AND CEREBROSPINAL FLUID

THE ARACHNOID AND PIA MATER. These delicate membranes are applied closely to the superficies of the brain, bound the subarachnoid space, and contain the cerebrospinal fluid.

The arachnoid forms an uninterrupted covering for the entire brain and spinal cord, bridging the sulci between the gyri and spreading across other depressions between larger eminences. The pia mater, however, is closely applied to the brain; as a result, the subarachnoid space, between the pia and arachnoid, normally varies in depth and may be increased in certain pathologic conditions. Delicate arachnoidal trabeculae extend from the arachnoid to the pia and bind the two membranes together so that they are often termed the pia-arachnoid (Figs. 21, 22).

The arachnoid is avascular; the blood vessels of the brain and spinal cord lie within the pia mater. Hemorrhage from these vessels passes into the subarachnoid space; there the blood mixes rapidly with the cerebrospinal fluid and diffuses throughout the subarachnoid space. The cerebral vessels, as they penetrate the brain, are surrounded by the pia-arachnoid; in this way the subarachnoid space is prolonged into the depths of the brain. The arachnoid also extends into the venous sinuses, particularly the superior sagittal sinus, in the form of tuftlike projections called pacchionian granulations or arachnoid villi (Fig. 21). These nodule-like extensions of the subarachnoid space contain cerebrospinal fluid, which is separated from the venous blood of the dural

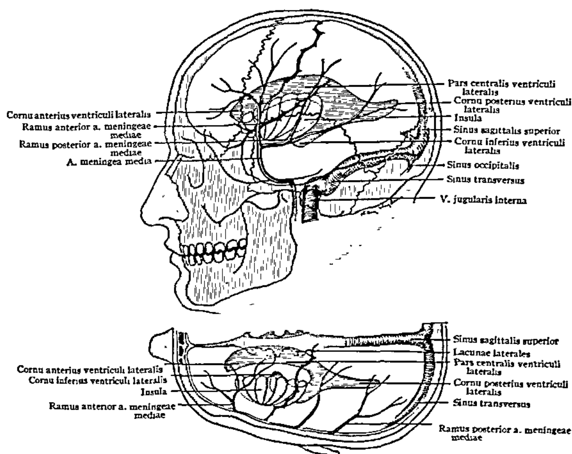


Fig. 18. RELATIONS OF THE MIDDLE MENINGEAL ARTERY WITH THE CRANIUM, INSULA AND THE LATERAL VENTRICLES.

(After Cushing.)

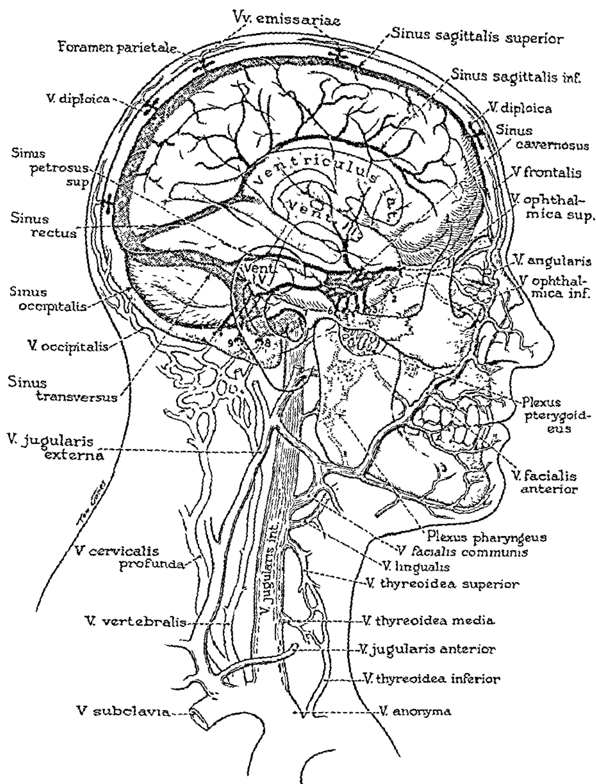


Fig. 17. VENOUS DRAINAGE OF THE HEAD AND NECK.

The numbers indicate the foramina through which these veins enter the cranium: 1, fissura orbitalis superior; 2, fissura orbitalis inferior; 3, foramen ovale; 4, foramen spinosum; 5, foramen lacerum; 6, canalis caroticus; 7, foramen jugulare; 8, canalis hypoglossi; 9, canalis condyloideus. The black inverted crescents indicate openings through which emissary veins pass. (Adapted from Jones and Shepard; Manual of Surgical Anatomy.)

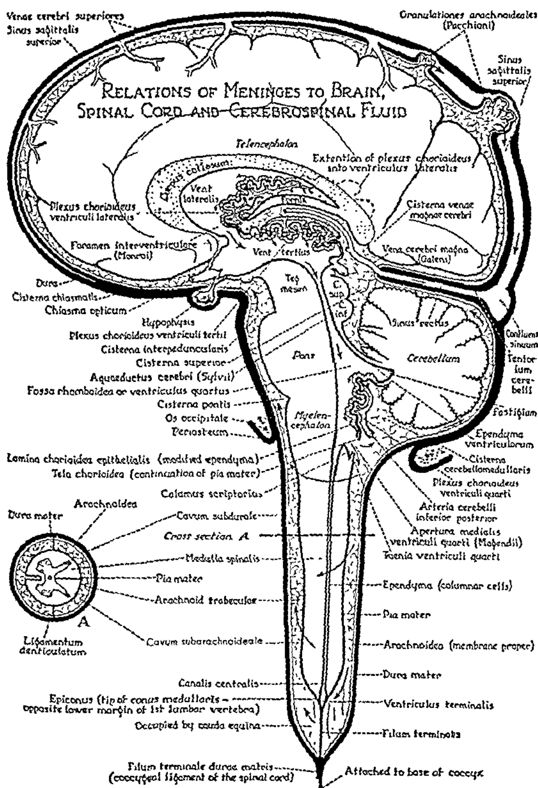


Fig. 20. DIAGRAM OF THE MENINGES, BRAIN VENTRICLES, AND SUBARACHNOID SPACES.
The arrows indicate the direction of the flow of the cerebrospinal fluid. (From Rasmussen: The Principal Nervous Pathways, Macmillan Company.)

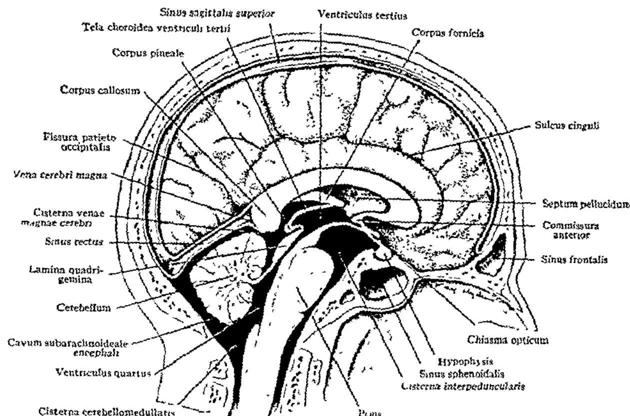


Fig. 19. VENTRICULAR AND SUBARACHNOID SPACES VIEWED IN MEDIAN SAGITTAL SECTION OF THE HEAD.

sinuses by nothing more than a thin covering of arachnoid and the endothelium of the sinus. The arachnoid is especially thin over the surface of the cortex, relatively thick over the brain stem and spinal cord. The arachnoid may become thickened in various pathologic states.

The subarachnoid space is considerably enlarged in several localities. These areas have been termed cisterns and are usually named for neighboring structures. They are of considerable clinical importance, since, with appropriate radiologic techniques, they may be visualized. The more important of these are the *cisterna chiasmatica*, situated above the optic chiasm; the *cisterna interpeduncularis*, anterior to the cerebral peduncles; the *cisterna pontis*, located anterior to the pons; and the *cisterna ambiens* (*cisterna venae cerebralis magnae*), posterior to the mesencephalon. The *cisterna magna*, or cerebellomedullary cistern, occupies the space between the inferior surface of the cerebellum and dorsal surface of the medulla (Fig. 19). These subarachnoid spaces communicate with one another and, through the foramen of Luschka and foramen of Magendie, with the ventricular system. The communication between these various spaces is important, inasmuch as it constitutes the pathway of circulation of the cerebrospinal fluid (the "third circulation," as it was named by the late Harvey Cushing).

THE CEREBROSPINAL FLUID. The cerebrospinal fluid, filling the subarachnoid space and cerebral ventricles, is clear and colorless and contains all the noncellular constituents of blood. It has long been thought to arise through the activity of the choroid plexuses in the lateral, third and fourth ventricles; then, after circulating within the ventricular system, it reaches the subarachnoid space—there to be resorbed (Fig. 20). However, recent studies have shown that its metabolism is probably far more complex than was formerly believed.

The cerebrospinal fluid provides a liquid support for the brain and spinal cord, and in all probability is involved in their metabolism. Specimens of the fluid may be most easily removed by puncture of the subarachnoid space, usually in the lumbar region, and the study of the chemical and cellular elements yields a great deal of information to the clinician.

concerned. Consequently the surgeon is obliged to deal more frequently with obstructions of the cerebrospinal fluid pathways which would lead to various forms of hydrocephalus.

HYDROCEPHALUS. From ancient times hydrocephalus has been recognized as a disease entity, and much effort has been expended through the ages towards its alleviation. It is the terminal result of a disturbance of the metabolism and circulation of the cerebrospinal fluid as a defect in either formation or resorption. The resultant excess of cerebrospinal fluid leads to a dilatation of the ventricular system and to consequent loss of cerebral tissue. On this basis, hydrocephalus can be divided into two types: in the one there is an obstruction to the normal circulation of the fluid, to produce an obstructive or noncommunicating hydrocephalus; in the other there is a defect in the production-absorption mechanism, causing a condition termed nonobstructive or communicating hydrocephalus.

Most frequently hydrocephalus is the result of obstruction to circulation or defect in resorption. Seldom is an overproduction of cerebrospinal fluid the cause of hydrocephalus. Common sites of obstruction are at the foramen of Monro, the third ventricle, the aqueduct of Sylvius, the foramina of Luschka and Magendie, the cisterna magna, and the basilar cisternae. These obstructions may be due to neoplasm, to congenital malformations or to inflammatory or postinflammatory reaction caused, respectively, by hemorrhage or infection. Failure in the process of normal absorption, secondary to meningeal inflammation, seems to rank first among the several possible causes of hydrocephalus.

In recent years many ingenious surgical procedures have been devised to delineate the site of obstruction and then to circumvent it. One of the currently popular therapeutic methods is ventriculocisternostomy, as originated by Torkildsen. In this procedure a catheter is used to pass ventricular fluid from one of the lateral ventricles (in a route beneath the scalp) into the cisterna magna, thus by-passing an obstruction which might be present in the third ventricle, aqueduct or at one of the foramina. For nonobstructive hydrocephalus, surgeons have sought to reduce the formation of cerebrospinal fluid by destroying the choroid plexuses, or by making available other avenues of excretion or resorption. In the latter instance pathways into various body cavities are established, the fluid being shunted into the peritoneal or pleural cavity or into the middle ear. Unfortunately, these methods may open the way for meningitis or encephalitis. The most successful form of operation is one which creates a passage from the subarachnoid space into one of the ureters, thus allowing the excess cerebrospinal fluid to pass out with the urine.

CONGENITAL DEFECTS AND DERMAL SINUSES. Congenital defects in the bony or membranous covering of the brain may lead to protrusion of the intracranial contents. These defects usually occur in the midline, most commonly in the occipital region; however, protrusions may occur anteriorly, to present through the longitudinal plate of the ethmoid bone. When the protruding mass contains only meningeal tissue and subarachnoid fluid, it is called a meningocele; an extrusion containing cerebral tissue is termed a myelomeningocele. Their importance lies in recognition, especially since those situated anteriorly may be mistaken for nasal polyps. Repair may be difficult; as previously mentioned, cerebral fungus may result from improper dural closure.

Congenital dermal sinuses may occur in the occipital region, and in that situation are likely to be associated with an intracranial mass of neuroectodermal dermal inclusions. Such sinuses are of greatest importance,. since, through them, infections which were originally external may lead to severe meningitis. Tumors of the meninges, the meningiomas, are of fairly common occurrence among intracranial tumors generally. Fortunately, most of them are histologically benign; but, unfortunately, they are frequently so situated as to make their complete removal difficult; they are likely to be associated with the large venous sinuses of the dura mater, and have an overabundant blood supply of their own. They may also invade bone locally. In this way they produce structural changes which are readily detectable on routine roentgenograms.

Brain

BRAIN IN GENERAL

The neurological surgeon is obliged to deal with injuries, vascular disturbances, tumors of the brain, as well as such conditions as epilepsy. By means of operations on the brain and cranial nerves, he may also be called upon to relieve pain and, through such procedures as hypo-

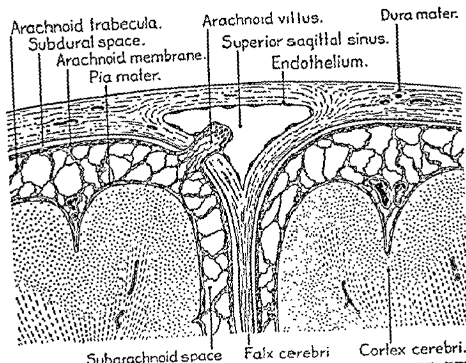


Fig. 21. DIAGRAMMATIC REPRESENTATION OF A CORONAL SECTION THROUGH THE SUPERIOR SAGITTAL SINUS TO ILLUSTRATE THE MENINGES. (Weed.)

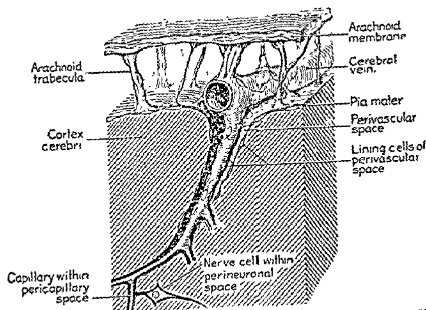


Fig. 22. DIAGRAMMATIC REPRESENTATION OF THE ARACHNOID AND PIA MATER TO ILLUSTRATE THE SUBARACHNOID SPACE AND PERIVASCULAR CHANNELS. (Weed.)

Surgical Considerations

LEPTOMENINGITIS. The meninges may become inflamed as a primary specific disease in case of various bacterial, mycotic or viral infections. They may also become inflamed as the result of infections of the brain or spinal cord. In times past, meningitis of almost any type was invariably fatal, as a result either of the primary disease or of postinflammatory disturbance in the flow of cerebrospinal fluid. With the availability of modern antibiotic therapy the mortality rate has decreased so far as the primary effects of bacterial invasion are

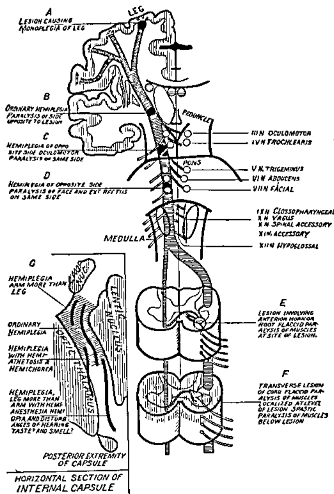


Fig. 24. EFFECT OF LESIONS (INDICATED BY CIRCLES) OF THE MOTOR PATH IN THE BRAIN AND SPINAL CORD. *G*, Internal capsule lesions and the variation in symptoms caused by lesions in a variety of locations. (Butler.)

from the ipsilateral jugular vein. There is even less communication, and consequent exchange, between the internal and external carotid systems. However, under abnormal circumstances adequate anastomotic channels may become available between these two vascular divisions, as well as between vessels of the two sides, and between the carotid and vertebral systems. Thus it is not unusual to find that surgical ligation of a carotid artery causes no neurologic deficit. In fact, a relatively large number of bilateral carotid ligations have been reported. Unfortunately, this is not always the case, simply because adequate anastomotic channels are not uniformly available, and such factors as anesthesia and the general condition of the patient may play an important role.

The *internal carotid arteries* supply the supratentorial parts of the brain. The vertebral arteries supply the infratentorial parts of the brain; additionally, by their terminal branch (the posterior cerebral artery) each supplies the occipital lobe, as well as much of the temporal lobe.

The internal carotid artery enters the skull through the carotid canal. Then, in its passage through the petrous portion of the temporal bone, the artery makes a series of sharp bends in several directions, finally entering the cranial cavity and penetrating the outer layer of the dura. After that it passes into the cavernous sinus, there lying lateral to the upper part of the body of the sphenoid bone, in a shallow groove (the carotid sulcus). At the posterior border of the clinoid process the artery leaves the cavernous sinus and passes through the inner layer of the dura mater. Then it courses posteriorly and laterally to the level of the posterior clinoid process, where the *posterior communicating artery* arises. The artery then

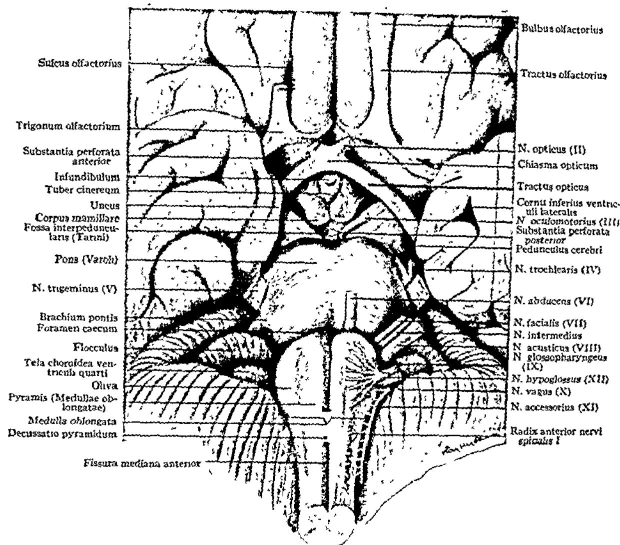


Fig. 23. BASE OF THE BRAIN.

Part of the temporal lobe is removed on the left side. All the nerve roots emerging on the right side, except the trigeminus, are removed. Part of the olfactory tract is removed to show the olfactory sulcus.

physectomy, attempt alleviation of malignant tumors elsewhere. Since the brain is so well protected by its coverings, an accurate preoperative localization is essential. This calls for a detailed knowledge of the form and function of the intracranial contents (Figs. 23 to 26).

Blood Vessels of the Brain. In recent years man's knowledge of the function and anatomy of the cerebral blood vessels has increased tremendously. Much of this increase is due to the use of cerebral angiography, as used by the neurological surgeon, not only in the study of primary disease of the cerebral vessels, but also in the diagnosis of brain tumors.

The brain receives its blood supply through the two internal carotid and vertebral arteries (Figs. 25, 26). The metabolic requirements of the brain are such that, at normal temperatures, interruption of cerebral blood flow for even brief periods of time, measured in minutes, causes severe and irreparable damage. The cerebral arteries differ from those elsewhere in the body in that they are little influenced by the sympathetic nervous system, but are markedly affected by chemical changes in the blood. They also differ histologically, in that the fibroelastic layer of the *tunica media* is sparse, with little or no muscular support.

The cerebral blood vessels, especially in their finer ramifications, supply particular areas of the brain—there is little mixing of the blood of one vessel with that supplied by another. This is also true of the carotid vessels. In experimental studies it was determined that almost three-fourths of a sample of dye-stuff injected into one carotid could be recovered

the sylvian vessels lie over the cortex close to the calvarium. The middle cerebral arteries supply the greater portion of the temporal and parietal cortex, whereas the anterior cerebral arteries supply the frontal cortex (Fig. 25). From the central portions of both the anterior and middle cerebral arteries a series of small vessels arises to supply the deeper intracerebral structures, the internal capsule and globus pallidus.

The *vertebral arteries* of either side enter the skull through the foramen magnum, and lie in the subarachnoid space just anterior to the medulla. They join to form the *basilar artery*, which passes superiorly between the pons and basisphenoid. In its upward course the artery gives off several paired branches to supply the brain stem and cerebellum. Several of these, such as the inferior and superior cerebellar arteries, when occluded, give rise to neurological disturbances that are quite characteristic. The basilar artery eventually divides into the two posterior cerebral arteries that pass horizontally and posteriorly beneath the occipital lobe, which they supply (Fig. 25).

The preceding descriptions may seem to the casual reader somewhat more detailed than necessary. However, an even more intimate knowledge is necessary for the practicing neurological surgeon, since cerebral angiography is one of his most important diagnostic tools.

Displacement of these arteries by tumors or other space-occupying masses is common. Therefore an exact knowledge of the normal positions of the cerebral arteries—especially as they appear on roentgenograms—is required. In such instances clinical examination is all that the surgeon needs to make an accurate diagnosis as to tumor type and localization. Cerebral vascular occlusions may also be confirmed by angiography, and in this way differentiated from neoplasms. Aneurysms or small, thin-walled saccular lesions of the cerebral arteries are a common cause of subarachnoid bleeding. Their accurate localization is an essential prerequisite to proper care.

The *arterial circle* (of Willis) consists of a hexagonal arrangement of arteries formed by the anterior, middle and posterior cerebral arteries, joined together by the anterior and posterior communicating vessels. The circle lies in relation to the optic nerves and the nerves supplying the extraocular muscles; it surrounds the infundibulum. There is a great deal of variation in the size of its component arteries; often one or more of the communicating vessels may be absent, or so small as to have little function.

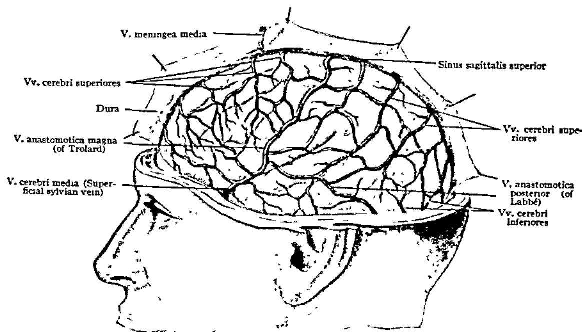


Fig. 26. LATERAL VIEW OF THE VEINS OF THE CEREBRUM.
The dura is reflected. (After Rouvière.)

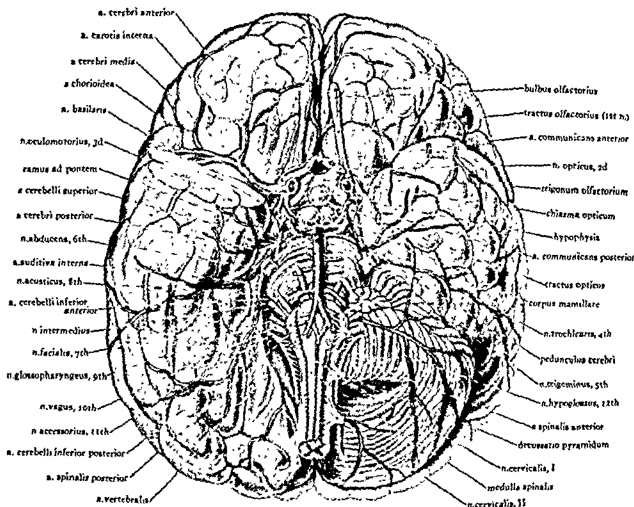


Fig. 25. THE ARTERIES AND NERVES ON THE INFERIOR SURFACE OF THE BRAIN (ENCEPHALON).
The anterior portion of the temporal lobe and the cerebellum have been cut away on the right side. (From Warren: Handbook of Anatomy, Harvard University Press, Cambridge.)

turns anteriorly; after making a curve it divides into its two principal branches, the middle and anterior cerebral arteries (Fig. 25).

The *ophthalmic artery* is the first intracranial branch of the internal carotid, arising even before the posterior communicating artery or before the bifurcation into the anterior and middle cerebral arteries. The *anterior choroidal artery* also arises from the carotid just above the posterior communicating branch. The portion of the internal carotid between its passage through the dura proper and its bifurcation into the anterior and middle cerebral arteries is known as the "carotid siphon," because it appears on lateral angiograms taken with a lateral projection as an S-shaped curve. It may be either single or double. The anterior cerebral artery passes anteromedially in a horizontal plane for a short distance; beneath the frontal lobe it swings superiorly to pass between the two frontal lobes and to lie just above the corpus callosum. It divides in its course into two main branches, the *pericallosal artery* and the *frontopolar artery*. As the two anterior cerebral arteries approach the midline, they are joined together by a short anastomotic vessel, the *anterior communicating artery* (Fig. 25). This vessel, however, is not always present.

The *middle cerebral artery* could be more appropriately called the sylvian group of arteries, because it usually consists of a leash of three principal branches: the posterior temporal, the artery of the angular gyrus, and the posterior parietal artery. The middle cerebral artery begins as a laterally directed vessel situated beneath the anterior perforated substance; it courses upward along the greater wing of the sphenoid, lying superior to the temporal lobe; finally it enters the sylvian fissure. In their terminal portions the various branches of

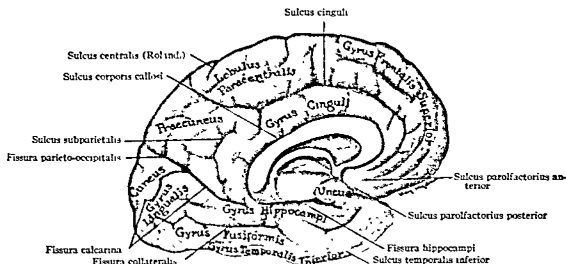


Fig. 28. SULCI AND GYRI ON THE MEDIAL ASPECT OF THE CEREBRAL HEMISPHERE.

body half, and that certain functions are represented in more or less well defined cortical areas. Briefly, localization may be described as follows: the main motor area lies just anterior to the rolandic fissure (Fig. 27); the functional areas concerned with movements of the legs and feet are located superiorly near the midline, and those of the face and upper extremities are near the sylvian fissure (Fig. 29); the main sensory area lies just behind the rolandic fissure (Fig. 28). Other secondary motor and sensory areas have been found. The frontal lobes have to do with the patient's emotional state, the temporal lobes with audition and vision, and the occipital lobes with vision. One hemisphere, most frequently the left, is the so-called dominant hemisphere because lesions affecting it, particularly in the region of the inferior frontal gyrus (Broca's area), result in speech disturbances.

The cerebellum lies in the posterior cranial fossa beneath the tentorium (Fig. 23). It is joined to the pons and other parts of the nervous system by three cerebellar peduncles. The cerebellum is divided into two hemispheres and may be regarded as consisting of several lobes. It is concerned with the modulation of a great number of activities of both the sensory and motor spheres, especially with coordination of motor activity.

At this point it may be worth while to make available to the reader a more detailed account of cerebral and cerebellar localization, as presented in standard sources.

MAIN AND SPECIALIZED MOTOR AREAS. The MAIN MOTOR AREA is limited to the gray matter of the narrow rolandic strip of the anterior central gyrus (Figs. 27 to 30). It is a centimeter in width and extends to the depth of the central fissure. Since much of this area lies hidden in the longitudinal fissure, the lesion which actually involves this cortex may lie below the exposed surface of the hemisphere. The inferior boundary of the motor strip falls short of the lateral cerebral fissure (of Sylvius). Generally speaking, the upper part of the area presides over the movements of the lower extremity, the middle region over those of the upper limb, and the lower part over those of the mouth, eyelids, tongue, pharynx and larynx.

The central sulcus is not straight, but is broken by several well developed angulations (Figs. 27, 28). Above the superior genu there is exposed only a small triangle of motor cortex, the area for the lower limb, where stimulation results in movements of the hip, knee and toes. The area for the upper extremity corresponds to the middle third of the precentral gyrus. The shoulder center is highest, followed by the centers for the elbow, wrist and fingers. The area for the neck and face continues downward from the area for the upper limb, the eyelid center occupying the highest position, succeeded below by the mouth and tongue. The area for the tongue occupies the lower extremity of the precentral gyrus and adjoins that for motor speech, which occupies the posterior and inferior parts of the inferior frontal convolution. The areas for the head and eyes occupy parts of the superior, middle

Usually the artery does not act as a distributing or mixing point, inasmuch as there is normally little commingling of the cerebral arterial blood. Should one of the carotid vessels be occluded, either through surgical ligation or as the result of thrombosis, the vessels of the circle provide anastomotic channels. In a similar situation the direction of blood flow through the ophthalmic vessels may be reversed; under these conditions the cerebrum receives blood from anastomoses with the external carotid.

Aneurysms of the cerebral arteries occur commonly in or near the circle of Willis. Aneurysmal pressure on the cranial nerves that supply the extraocular muscles causes visual disturbances, particularly diplopia. Rupture of such an aneurysm results in bleeding into the subarachnoid space. The internal carotid artery may be injured by a basilar skull fracture. A fistulous connection between the artery and the cavernous sinus may be the result of such an injury. This condition leads to a characteristic symptom-complex of pulsating exophthalmos, owing to a pulsatile flow of arterial blood into the veins which drain the orbit.

CEREBRAL CORTEX AND CEREBELLUM

The cerebral hemispheres of the brain are usually anatomical mirror images; however, they are not functionally equivalent. The hemispheres have been divided into various lobes (Fig. 27), according to the bones which covered them. Although there may be anatomical justification for such parcellation, there is little to justify such a division from a functional standpoint. It is still true that subdivision of the cerebral cortex provides a point of departure for further study.

Roughly speaking, the frontal lobes are bounded posteriorly by the rolandic fissure; it separates the frontal from the parietal lobes, and the latter are separated from the occipital lobes by the parieto-occipital fissure (Fig. 28). The temporal lobes are set off from the frontal and parietal lobes by the sylvian fissure and the vein of Labbé.

In the brain of the living person it is often difficult to identify the various fissures. Some anatomists have also attempted a classification of the areas of the cerebral cortex on the basis of distribution of cortical cell structure. More recently a classification based on the effects of electrical stimulation of the cortex has been made. Generally speaking, none of the systems is entirely satisfactory; however, each of them offers moderate help (pp. 29 to 32). As a minimum, the clinical surgeon should know that one hemisphere represents the contralateral

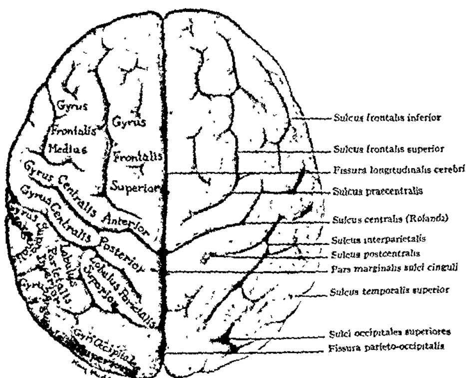


Fig. 27. GYRI AND SULCI OF THE SUPERIOR SURFACE OF THE CEREBRUM.

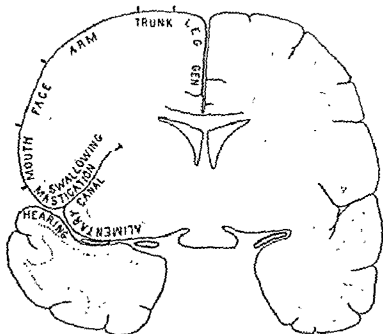


Fig. 30. DIAGRAM OF A FRONTAL SECTION THROUGH THE CEREBRUM SHOWING THE MAJOR SUBDIVISIONS OF THE PATTERN OF REPRESENTATION OF MOTOR AND SENSORY AREAS AND THE ALIMENTARY SYSTEM.

Determined by cortical stimulation *T*, Tentative location of area representing taste. *Gen.*, Genital region. (Modified from Penfield and Rasmussen, 1950.)

and inferior frontal gyri, in front of the areas for the limbs.

Destruction of these areas leads to complete and permanent loss of movement in proportion to the extent of the lesion and the degree of bilateral representation of the movements concerned, but sensation is not affected. The motor pathway from the cortical centers is the pyramidal tract, the fibers of which degenerate through their full length after injury to the cortical cells.

The SPECIALIZED MOTOR AREAS are those concerned with speech and writing. The *center for motor speech* is conceded to be in the posterior end of the left inferior frontal gyrus (Broca's convolution). A lesion here produces motor aphasia, inability to transform concepts into words, although the vocal cords and tongue are capable of functioning. The *writing center* has been placed at the posterior extremity of the middle frontal gyrus, that is, near the primary cortical centers for movement of the hands and fingers (Fig. 31). A lesion here produces agraphia, inability to transfer a concept into written form.

MAIN AND SPECIALIZED SENSORY AREAS. The MAIN SENSORY AREA occupies the postcentral convolution, a position behind the central sulcus analogous to that of the motor area in front of it. Similarly, much of it lies hidden on the anterior wall of the gyrus within the central sulcus. The cortical area for *pain* and *temperature* probably lies a little behind the postcentral cortical sensory area, and that for *stereognosis*, recognition of objects by sense of touch, lies in the parietal lobe.

SPECIALIZED SENSORY PATHWAYS terminate in reasonably sharply circumscribed cortical areas which, for the most part, are separated widely from one another by masses of cortical substance.

The *center for reception of visual impressions* has been traced to the occipital lobe (Figs. 31, 32). The *visual word center for reading* has been placed definitely in the angular gyrus, and a lesion in it probably causes a loss of ability to read or understand written language, although ordinary sight is not disturbed.

The *auditory center* is in the superior temporal convolution (Figs. 30, 31). Sensations are converted into conscious perceptions in this and adjacent parts of the temporal lobe. Those on the left side are bound up particularly with the auditory function of speech mechanism. It is probable that the center for each side is connected with both auditory nerves, so that a

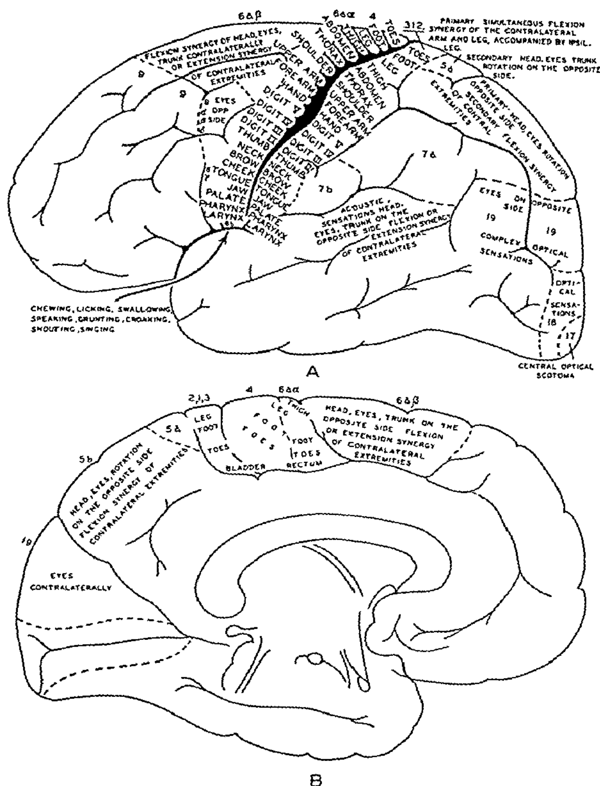


Fig. 29. DIAGRAMS TO SHOW REPRESENTATION OF MOVEMENTS, SIMPLE AND COMPLEX, IN THE CEREBRAL CORTEX OF MAN.

Determined through electrical stimulation by Foerster. *A*, Lateral cortical surface; *B*, medial cortical surface. (From Bumke and Foerster: "Handbuch der Neurologie," Vol. 6, copyright 1936 by Julius Springer in Berlin. Printed in Germany. Vested in the U.S. Attorney General.)

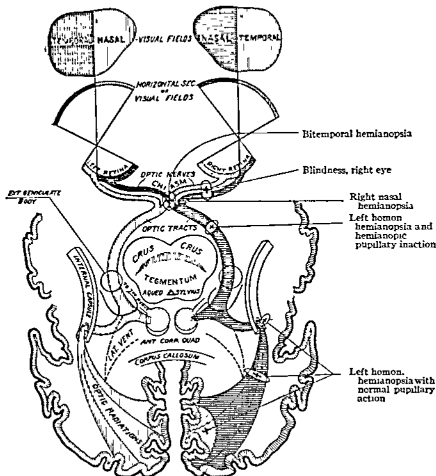


Fig. 32. DIAGRAM OF THE OPTIC TRACTS AND VISUAL FIELDS.

Lesions at different points in the tract, causing hemianopsia, are indicated by + (From Moorhead: Traumatic Surgery.)

Surgical Considerations

Although the cerebrum is subject to a great variety of lesions, the symptoms and signs manifested are relatively few and depend more upon the location of the pathologic process than upon the process itself. Any obstructive lesion in the motor path at any point between the cortex and the peripheral end organ, whether neoplasm, hemorrhage, thrombosis, inflammation, injury or compression, produces paralysis.

While there may be a physiologic interruption of nerve pathways without pressure signs or symptoms, certain evidences frequently accompany increased intracranial pressure. Chief among these are headache, vomiting, choked disks, vertigo and convulsions. Focal symptoms and signs, when present, determine the location of the lesion; they are confined generally to disturbances of motion, common sensation and the faculties of special sense.

REGIONAL DIAGNOSIS IN THE VARIOUS AREAS OF THE CEREBRAL CORTEX AND CEREBELLUM. The surgical accessibility and the fairly definite motor and sensory symptoms of lesions about the central sulcus of Rolando partly account for the success which brain surgery has attained. Lesions in this region involve the sensory receiving stations lying behind the fissure and the motor discharging stations in front of it. The motor neurons from the precentral gyrus comprise the pyramidal tract (p. 31) and pass to the spinal cord, crossing (decussating) in the medulla. The afferent, or sensory, impulses reach the postcentral gyrus through relays of neurons, the last of which form a group of radiating fibers which arise from cells in the thalamus. Therefore any motor or sensory disturbance originating in the cortex manifests itself in that half of the body opposite the side involved in the lesion.

An irritative disease in the MOTOR AREA and PATHWAY which is confined to a single group

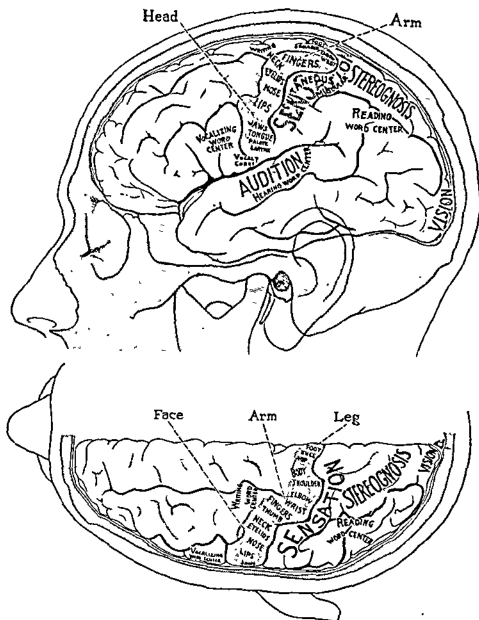


Fig. 31. LOCALIZED CENTERS OF THE EXPOSED SURFACE OF THE CEREBRAL HEMISPHERE, SHOWN IN RELATION TO THE MAIN FISSURES AND CONVOLUTIONS.

The position of each center is shown in lateral (*upper figure*) and in superior view (*lower figure*). (From Cushing, in Keen's Surgery.)

paralysis of one side by a unilateral lesion may be compensated by the center on the opposite side. The cortical center for the *recognition of spoken words* lies above the primary area for hearing in the superior temporal gyrus of the left temporal lobe and is the first center which is developed in the faculty of language (Fig. 31).

The centers for smell and taste are not so definite. The center for *smell* is thought to lie in the uncus, and that for *taste* in the hippocampal gyrus (Fig. 28). These are important considerations, since lesions in these areas not only give characteristic symptoms, but also are accessible surgically.

Cerebellum. The cerebellum rests in the posterior cranial fossa below the tentorium and behind the pons and medulla oblongata. It is the largest part of the hindbrain, and between it and the pons and medulla lies the fourth ventricle. *The cerebellum consists of three* parts: a median, the vermis, and two lateral expansions, the hemispheres (Figs. 23 and 33). The cerebellum is connected to the cerebrum, pons and medulla oblongata by superior, middle and inferior peduncles.

tween the postcentral sulcus and the occipital lobe and does not include the postcentral gyrus. *Word blindness*, or inability to understand written language, is a characteristic symptom complex which follows a destructive lesion of the angular gyrus of the left side in right-handed persons. A deep-seated lesion involving the paths radiating from the word-perceiving center also may involve the optic radiation and lead to half-blindness of the corresponding sides of both retinas. A lesion of the upper parietal lobe, particularly when subcortical, produces *astereognosis*, the inability to recognize through contact the form or character of objects.

The OCCIPITAL LOBE includes the posterior extremity of the hemisphere on both its outer and inner aspects. Mesially, it contains the cuneus and the lingual gyri, from which region the *optic radiation* passes by the wall of the posterior end of the internal capsule to the thalamus, whence it runs by way of the optic tracts to the retinas (Fig. 32). A destructive lesion of this portion of the occipital cortex causes blindness on the homolateral halves of both retinas, or *homonymous hemianopsia*. The patient then is unable, when looking directly forward, to see objects on the side opposite from the lesion until they are brought across the median plane. In hemianopsia from cortical lesions the pupils react in the usual manner, since the fibers from the oculomotor nerves are not involved. The location of lesions of other varieties of hemianopsia is indicated in Figure 32.

The main portion of the under surface of the cerebral hemispheres is formed by the TEMPORAL LOBES. They are particularly susceptible to injury in basal fractures; they may harbor an extensive latent abscess. *Word deafness*, or the inability to understand spoken language, is pathognomonic of a lesion of the superior temporal gyrus on the left side. The same lesion also may affect the entire speech mechanism so that word blindness and motor aphasia accompany it. The antero-inferior extremity of the lobe, forming the uncus of the hippocampal gyrus, is associated with the senses of *taste* and *smell*, and a destructive lesion here will destroy both (Fig. 28).

CEREBELLAR tumors, cysts and abscesses may require surgical treatment. The symptoms of these lesions are instability in equilib- ıd locomotion, and troublesome vertigo. A coarse ataxia accompanies voluntary movements, and nystagmus is a frequent sign. The symptoms are bilateral when the lesion occupies the middle lobe of the cerebellum, and homolateral when a lateral lobe is affected. Rotary movements and a tendency to turn or fall toward the affected side perhaps result from ataxia and weakness of muscle control on that side.

INTRACRANIAL GLANDULAR STRUCTURES. The essential glandular structures are located within the cranial confines. One, the pituitary gland or hypophysis, is located in the anterior fossa in the sella turcica. It is contained in its own dural compartment, with important surgical relationships to the optic nerves and chiasm. These structures may be compressed by the growth of pituitary tumors, with resultant impairment or loss of vision. The pituitary gland is composed of several parts, the adenohypophysis, or anterior lobe, and the neurohypophysis, or posterior lobe. The adenohypophysis has far-reaching endocrine influence, affecting as it does the secretions of the thyroid, adrenals, pancreas and gonads. The neurohypophysis is concerned with water metabolism and with functioning of the uterus. Because of these effects, it has been termed the master gland of the body. This gland is surgically important because tumors may be derived from its substance, and because extirpation sometimes influences the growth and behavior of tumors elsewhere, *i.e.*, those of the breast and prostate.

The pineal gland is situated at the posterosuperior part of the third ventricle (Fig. 33). Although it is rarely the site of tumorous growth, the gland provides the surgeon with valuable assistance in diagnosis of other tumors of the cerebrum. In a large percentage of normal adults the pineal gland contains sufficient calcium to render it visible on ordinary roentgenograms. Shifts of the pineal gland from its normal midline position may be due to a tumor elsewhere.

CEREBRAL VENTRICLES. *Pneumoencephalography*. The brain, far from being a solid structure, contains cavities called ventricles, which communicate with the subarachnoid space. Like the latter, the ventricles contain cerebrospinal fluid (the formation and circulation of which has been discussed on pages 20 to 22).

The lateral ventricles are contained within the cerebral hemispheres. Each may be divided into a middle portion, or cella media; an an-

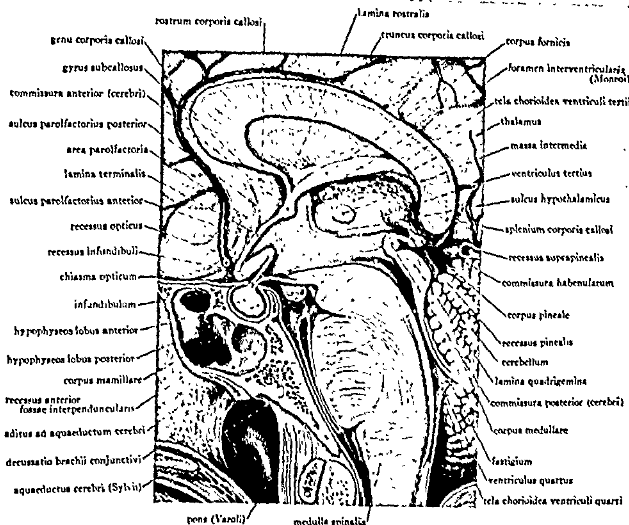


Fig. 33. MEDIAN SAGITTAL SECTION THROUGH THE ENCEPHALON AND THE BRAIN STEM.
(From Warren: *Handbook of Anatomy*, Harvard University Press, Cambridge.)

of cells may cause convulsive movements in the domain of the muscles controlled by these cells, termed attacks of focal or *jacksonian epilepsy*. It is characteristic of such a seizure that convulsive movements spread into groups of muscles, the cortical centers of which immediately adjoin those primarily irritated; in some instances the entire body musculature may become involved progressively. Any destructive lesion of the motor cortical area or pathway gives rise to loss of motion without accompanying loss of sensory perception.

A postcentral gyrus lesion involves the common SENSORY AREA and PATHWAY. Like lesions in the anterior gyrus, it may be irritative and result only in such forms of paresthesia as *numbness* and *tingling*. The lesion may be destructive and lead to *hypesthesia or anesthesia*. While cortical sensory lesions must be extensive to cause a considerable loss of sensation, subcortical lesions in the sensory pathway produce pronounced anesthesias.

While, anatomically, the FRONTAL LOBE extends to the central sulcus, clinically, the lobe is limited to that portion of the hemisphere which lies anterior to the precentral sulcus. The forepart of the frontal lobe, from the clinical standpoint, is a silent area. In the postfrontal region are located the centers for the conjugate movements of the head and eyes and the motor part of the mechanism of speech. The left inferior frontal gyrus (Broca's convolution) presides over motor speech, and a lesion here, particularly if subcortical, results in *motor aphasia*. A lesion in the posterior extremity of the middle frontal gyrus may result in *agraphia*, *inability to write*.

Clinically, the PARIETAL LOBE is the area be-

ods, the walls of the third ventricle, the various levels of the brain stem, and the recesses of the posterior cranial fossa offer only limited advantages to surgical exploration.

APPROACHES TO THE BRAIN. While the scalp is a well vascularized structure and heals kindly in most instances, nevertheless surgical incisions are planned for the preservation of blood and nerve supply so far as possible. The frontal lobes, and genu of the corpus callosum, the third ventricle, the region of the sella turcica and the floor of the anterior cranial fossa may be reached through an anterior, or so-called transfrontal, osteoplastic craniotomy. For example, the skin incision, made upward from the midbrow region, follows the sagittal suture line, curving at last over to a point slightly in front of the ear and above the zygomatic arch. All layers of the scalp, skin, galea, aponeurosis, muscle and pericranium are carefully accounted for and, together with the flap of incised bone still attached, are swung outward and down, hinged by the soft tissues of the temple region, where only the thin temporal bone has been cut or fractured through. Extradural procedures may then be carried out, but to have access to the brain the middle meningeal artery must be ligated and sectioned, after which a circular flap of dura mater, conforming to the actual bone opening, is made with the hinge in this case at the midline, where the sagittal sinus and veins draining the cerebrum are not molested. The bone is cut by specially devised instruments such as twisted wire saws, and, being cut on a bevel, the flap "seats" securely back into place at the end of the operation. For the purpose of allowing further room for a swollen brain, a large section of the squamous portion of the temporal bone, upward from the floor of the middle cranial fossa, may be removed; indeed, if need be, the entire bone flap in any location may be and frequently is removed completely, closure being effected by careful approximation of the muscle, aponeurosis, galea and skin, each in its own particular layer. To afford such decompression, the dura mater is left unsutured in the lower portion of its incision. Flaps are planned for efficiency of intracranial operation, for primary wound healing and the best obtainable cosmetic effect.

Other incisions include the large, semicircular frontoparietotemporal flap, again hinged through the temporal muscle and fascia, and the parieto-occipitotemporal flap, for access to the occipital region of the cerebrum, the splenum of the corpus callosum, the pineal region, and other deep areas lying dorsal to the midportion of the brain stem. In approaching the trigeminal nerve between the gasserian ganglion and the brain stem, the soft tissues are opened through a straight incision made upward from the zygomatic arch, and after a craniectomy has been made approximately 3 cm. in diameter just above the floor of the middle cranial fossa, the nerve is approached through an extradural route. The bone is not replaced, since, as in all other places where craniectomy is performed, the dense muscle and fascia layers surrounding the base of the calvarium give adequate protection to the underlying brain. Osteoplastic flaps are not ordinarily used to uncover the contents of the posterior cranial fossa, since the bone there does not lend itself to such technique and since actual craniectomy provides not only good postoperative decompression, but also a much needed wider exposure in this anatomically difficult location. Suboccipital craniectomy may be unilateral or bilateral, and may be extended to include laminectomy of one or more of the upper cervical vertebrae if need be. For bilateral craniectomy, which is the usual method, the skin with attached muscles and fascia is opened along the superior occipital line, stripped periosteally from the bone down to the foramen magnum, and held retracted while the bone is opened over the two cerebellar hemispheres, and the small occipital sinus is permanently ligated. Here again closure of the muscles, fascia and skin must be done in scrupulous manner.

Thus all surgical approaches to the brain and its various parts are made through openings in the calvarium, with the exception of the operation of suboccipital craniectomy in the occipital bone. No access to the intracranial cavity can be had through a basilar route save that of the trans-sphenoid approach to the hypophysis and optic chiasms, and practically all surgeons have abandoned that method.

terior portion, or horn; and temporal and posterior horns. Each of the horns lies more or less in the central portion of its lobe. A portion of the choroid plexus is situated in the posterior and temporal horns, as well as in the third and fourth ventricles (Fig. 33).

The two lateral ventricles communicate with *the third ventricle by the foramen of Monro.* The third ventricle lies in the midline; the hypothalamus forms its walls, and the corpus callosum is its roof. The third ventricle is joined to the fourth ventricle by the aqueduct of Sylvius, a canal of small diameter located in the diencephalon. The fourth ventricle, situated between the two cerebellar hemispheres and the medulla, empties into the cisterna magna through a medially situated foramen of Magendie (Fig. 20), and two laterally situated foramina of Luschka.

The ventricular system may be visualized by replacement of its normal fluid with a substance of greater or less radiologic density than that of the cerebrum; this may be air or oxygen or iodinated oil. The procedure may be carried out by direct injection of the media through a cannula passed into a trephine opening. This process is termed *ventriculography*. Air may be injected into the lumbar subarachnoid space, a procedure known as *pneumoencephalography.* In this procedure, with careful positioning of the patient's head, the gaseous medium will ascend, passing through the foramina of Magendie and Luschka, to fill the ventricular system—sometimes, too, the cerebral cisterns and subarachnoid spaces.

Pneumoencephalography and ventriculography are to be regarded as among the most useful diagnostic aids available to the neurological surgeon; through their use he is able to determine the presence and the location of expanding intracranial lesions, or to establish blockage of the flow of cerebrospinal fluid. He may also detect areas of cerebral atrophy or other degenerative lesions by the increased size of the ventricles or subarachnoid spaces. The procedures are not entirely innocuous, inasmuch as the removal of fluid, in the presence of increased intracranial pressure, may cause shifts of the intracranial structures. Ventriculography requires a surgical procedure which is usually done with a local anesthetic. Pneumoencephalography may cause considerable discomfort, especially if air escapes or enters the subarachnoid spaces in any considerable amount.

Cranial Nerves. The cranial nerves, motor and sensory, are of surgical importance not only from a diagnostic, but also from a therapeutic, standpoint. Loss of sense of smell may be the sign of a meningioma located in the olfactory groove, or caused by a basal skull fracture. Pituitary tumors cause characteristic alterations in the field of vision; tumors of the temporal and occipital lobes have a similar effect. The third, fourth and sixth cranial nerves may be compressed by carotid aneurysms. The sixth nerve, because of the length of its course, is especially vulnerable in head injuries. Tic douloureux, or trigeminal neuralgia, is a neuralgic disease of unknown origin, which causes severe paroxysms of pain in the distribution of the trigeminal nerve. These pains are so severe that patients have committed suicide to escape their torture. The pain may be relieved by preganglionic section of the nerve, usually accomplished by approach beneath the temporal lobe. The glossopharyngeal nerve is also affected by a similar disease process; it may be sectioned in the posterior fossa as it passes into the jugular foramen. The vestibular portion of the acoustic nerve may require section in cases of intractable vertigo.

Patients with inoperable or advanced malignancies of the head and neck often live for many years, but suffer severe pain. Section of the trigeminal nerve (which carries sensation from the face) and of the glossopharyngeal nerve (which supplies the nasopharynx) brings considerable relief. Frequently transection of several of the upper cervical sensory roots must be done, since there is overlap of these nerves in their supply to the lower jaw and upper neck.

Surgical Access to the Brain. No part of the cerebrum, cerebellum or brain stem is inaccessible to the surgeon, since surgical approaches have been devised which allow operation upon all parts of the brain. This is not to say, however, that these various operations are done with equal ease or that all parts of the brain may be approached surgically with the same degree of impunity. Indeed, as if nature had wisely put almost out of reach of investigating fingers and instruments the most complex and vital parts of the intracranial contents, we find that, for all the ingenuity of surgical meth-

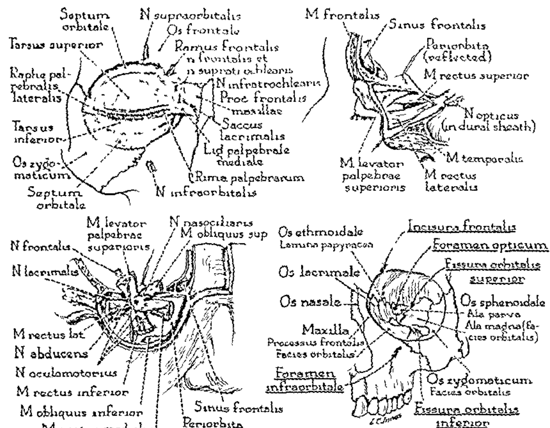


Fig. 35. ORBIT: ORBITAL SEPTUM, OCULAR MUSCLES AND OSSEOUS WALL OF THE ORBIT.

Upper left, the orbital septum and the cutaneous nerves of the supraorbital and infraorbital regions; *upper right*, the orbital muscles in lateral exposure; *lower left*, the orbital muscles (transected) and their nerves of supply, as seen from the front (optic nerve and bulb of the eye removed); *lower right*, skeletal elements which constitute the wall of the orbital cavity (Anson: An Atlas of Human Anatomy)

shaped roughly like a quadrilateral pyramid, although its rounded angles liken it somewhat to an irregular cone. The base, measuring about 4 cm. in width and a little less in height, opens on the face; the apex lies at the optic foramen. The orbital capacity more than accommodates the globe and its muscles, vessels and nerves. The unoccupied intervals contain orbital fat (corpus adiposum orbitae). This fat is differentiated into loculi by fibrous prolongations from the fascia of the bulb (Tenon's capsule) (p. 57).

ORBITAL MARGINS. The orbital margins, unlike the fragile and thin walls, are strong and resistant and are not injured easily (Figs. 35, 53, 54). The temporal margin recedes too far from the projecting eyeball to afford it adequate protection; hence eye injuries from blows occur most frequently from the temporal side. The superior margin is prominent and adequately protects the eye above. The mesial rim is less prominent, but protection to the globe is afforded by the bridge of the nose. Knowledge of the minute anatomy of this margin is important in the surgery of the lacrimal sac (p. 48). The entire orbital rim may be likened to a broken circular spring, the broken portion occurring at the mesial edge, where the two ends or crests overlap each other and separate slightly to enclose the lacrimal groove, in which lies the lacrimal sac. The crests are identified readily by palpating along the margins which form them. The anterior lacrimal crest is a continuation of the inferior orbital margin and is the essential landmark throughout the operation of tear-sac extirpation.

ORBITAL PERIOSTEUM. The lining periosteum, or *periorbita*, is thin but resistant, and is continuous posteriorly with the cranial dura. It is attached loosely to the subjacent bone, from which it may be elevated by pathologic effusions. At the lacrimal groove the periorbita splits to enclose the lacrimal sac. The layer roofing the groove is the *lacrimal fascia*, and

CHAPTER 2

Special Senses

Visual Apparatus

The visual apparatus includes the ocular globe, or eyeball, and its associated structures: the bony orbits, the palpebrae, or eyelids, the lacrimal apparatus, the fascia of the bulb (Tenon's capsule) and the retro-ocular structures (*Figs.* 34, 35, 38, 49, 53, 54).

ORBITAL REGION

DEFINITION AND BOUNDARIES. Each orbit is a deep cavity lateral to the nasal fossae; it is

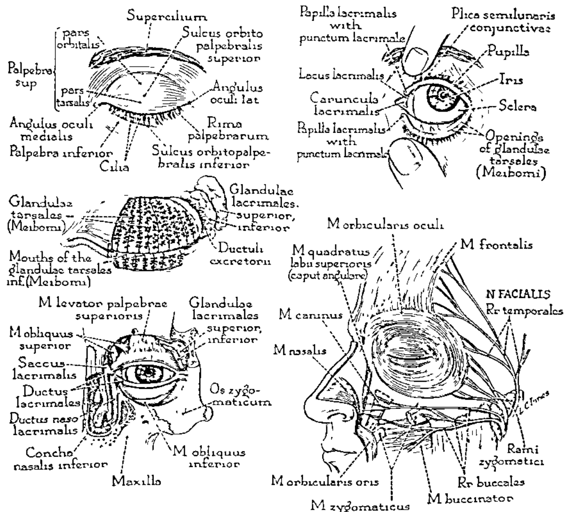


Fig. 34. EYE: EYELIDS, LACRIMAL APPARATUS, BULB OF THE EYE.

Upper left and right, palpebral topography and the lacrimal openings and spaces; respectively, with the eye closed and with the lids retracted. *Middle left,* the tarsal and the lacrimal glands and ductules. *Lower left,* the lacrimal glands and duct, and the nasal portion of the pharynx. *Lower right,* the orbicularis oculi and related muscles of facial expression, and the branches of the facial nerve. (Anson: An Atlas of Human Anatomy.)

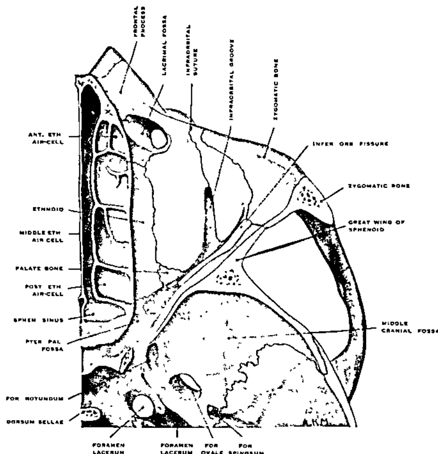


Fig. 37. FLOOR AND LATERAL WALL OF THE ORBIT.

The orbital floor is formed by the orbital surface of the maxilla, the orbital process of the zygomatic, and, to a small extent, posteromedially, the orbital process of the palatine. The lateral, or outer, wall is formed by the orbital process of the zygomatic and the orbital surface of the great wing of the sphenoid. (From Wolff: Anatomy of the Eye and Orbit, Blakiston, Philadelphia.)

mission of the supra-orbital vessels and nerves. Of the four walls, the *external* is the thickest and most solid, and the only one not in close connection with the paranasal sinuses. By resection of this wall, the contents of the orbit may be approached safely (p. 42).

The *apex* of the orbit is in communication with the cranial cavity through the superior orbital fissure and the optic foramen, the bony channels through which the orbital contents receive their nerve and vascular supply (Figs. 35, 53, 54). An instrument penetrating the orbit may fracture the walls and be driven into the cranial cavity or into the ethmoid or maxillary sinuses with little external evidence of the seriousness of the lesion.

Surgical Considerations

Tumors and Infections of the Orbit. *Tumors* of the maxillary sinus readily involve the orbit by invading the superjacent orbital floor. New growths may extend from the nose through the nasolacrimal duct into the orbit, or from the brain or cranial cavity through the optic and superior orbital openings. Invasion sometimes occurs by erosion of the bony walls. The retro-ocular space of the orbit may be the site of primary tumor. Failure of the nasal process of the frontal bone to reach that of the maxilla produces a cleft, the site for dermoid tumors which occasionally extend to the dura mater. Either dermoid tumors or meningoceles may occur at the frontonasal suture. While removal of a meningocele predisposes to meningitis, excision of a dermoid tumor may be accomplished more safely, since it usually has no connection with the cranial meninges.

The discrepancy between the capacity of the orbit and the bulk of its normal contents accounts for foreign bodies or tumors of an

should be recognized in dissection for tear-sac extirpation. About the inferior orbital fissure a smooth mass of orbital muscle is incorporated into the superficial aspect of the periorbita. This is a vestigial arrangement and may be a factor in production of the exophthalmos of Basedow's disease (exophthalmic goiter). The periosteum at the orbital margin is continued into the eyelids as a membranous septum, fusing in the lower lid with the tarsal plate and in the upper lid with the skin. This *orbital septum* defines the anterior orbital boundary (Fig. 53).

WALLS OF THE ORBIT. The *superior wall* or *roof* of the orbit is formed chiefly by the orbital plate of the frontal bone, and posteriorly by the lesser wing of the sphenoid bone (Fig. 36). It is part of the floor of the anterior compartment of the cranium and is related to the frontal sinuses. Mesially and anteriorly on the roof is a depression, the trochlear fossa, for the pulley of the superior oblique muscle (Fig. 37). The *inferior wall* or *floor* is formed by the orbital plate of the maxilla, the orbital surface of the zygoma and the orbital process of the palatine bone. Only the thin maxillary wall separates the orbital cavity from the subjacent maxillary sinus. This wall is liable to injury from resection of the maxilla for malignant growths, or to necrosis from inflammation in the underlying sinus. The frail *mesial* wall is in connection with the nasal fossa through the interposed ethmoid labyrinth and sphenoid sinus. Through it ethmoid disease may extend to the orbit. The mesial wall may be injured by operative manipulation among the ethmoid cells. At the antero-inferior margin of the mesial wall is the lacrimal groove for the lacrimal sac, or dilated end of the nasolacrimal duct, which opens into the inferior nasal meatus (p. 67). The antero-superior margin of the mesial wall presents the supra-orbital notch or foramen for the trans-

Fig. 36. ROOF AND MEDIAL WALL OF THE ORBIT.

The roof of the orbit is formed in the greater part by the orbital process of the frontal bone, in the lesser part by the sphenoid. The medial, or inner, wall is made up of the frontal process of the maxilla, the lacrimal, part of the body of the sphenoid and the *lamina papyracea* of the ethmoid. (From Wolff: Anatomy of the Eye and Orbit, Blakiston, Philadelphia.)

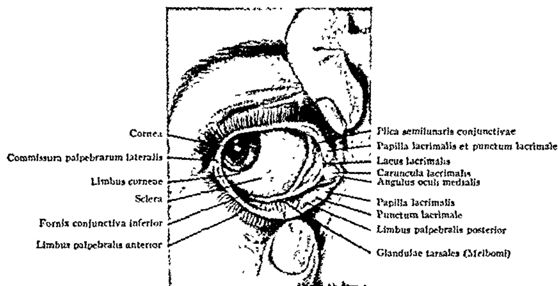


Fig. 38. SUPERFICIAL STRUCTURES OF THE EYELIDS

cornea from injury and to assist in keeping it from undue drying. The transverse opening between the free margins of the lids is the palpebral fissure, and the angles formed at the lid junctions are the medial and lateral canthi or commissures. Each lid, in its free margin near the medial canthus, is marked by a small tubercle, the lacrimal papilla, the summit of which presents a punctum, the beginning of the lacrimal drainage system (Figs. 34, 38). Both puncta lie in exactly the same vertical line, which relation must be maintained in suturing extensive lacerated wounds of the eyelids. Between the papilla and the rounded margins of the medial canthus is a space, the lacus lacrimalis, on the floor of which is a small, pale red body, the lacrimal caruncle. The cilia, or eyelashes, are arranged in an irregular line between the lacrimal papilla and the lateral canthus.

The skin of the lids is thin and elastic and is attached loosely to the underlying muscles, partly because of the absence of fat in the subcutaneous tissue. This laxity permits great distention by effusions, which, however, because of the firm attachment of the skin to the commissures, rarely extend from one lid to the other.

A "black eye" is usually due to local violence causing subcutaneous extravasation of blood into the lids. It also may result from a blow on the skull which causes bleeding into the subepicranial space. The blood, gravitating slowly forward under the frontalis muscle, appears in a day or two in the eyelids, first in the upper lid and then in the lower. Fracture of the orbital plate of the frontal bone causes bleeding into the orbit. The blood tracks forward under the conjunctiva and appears as a triangular, flame-shaped hemorrhage, with its apex at the corneal margin.

STRUCTURE OF THE EYELIDS. The *tarsus* is a thin, elongated plate of dense fibrous tissue which gives each lid its firmness (Figs. 39, 40). It is connected with the lateral wall of the orbit by the lateral palpebral raphe or external tarsal ligament, with the medial wall by the medial palpebral or internal tarsal ligament, and with the upper and lower orbital margins by an aponeurotic layer of fibrous tissue known as the orbital septum (orbital ligament, palpebral fascia). In parallel rows in the substance of each tarsus are the tarsal or meibomian glands, elongated sebaceous glands which open on the free margin of the lid, lubricate it, and prevent the overflow of tears.

The *orbital septum* (p. 40) is a membranous sheet attached peripherally to the periosteum of the orbital margin and centrally to the tarsal plates, thus preventing orbital extravasations from entering the lids. The palpebral portion of the orbicularis muscle overlies it, and to its upper portion the tendon of the levator palpebrae muscle is fused. In operations for cataract the fibers of the lid portion of the orbicularis oculi muscle may be injected with Novocain

astonishing size remaining unrecognized for long periods of time. Close connection of the orbit with the paranasal sinuses explains orbital infection complicating sinusitis.

ORBITAL HEMORRHAGE. In violent head contusions with basal skull fractures through the orbital roof, blood may find its way into the orbit and produce subconjunctival pericorneal hemorrhage, which, although not pathognomonic of actual fracture, is an important confirmatory sign. Entrance of blood into the lids is prevented by the intimate attachment of the orbital septum (p. 43).

ORBITAL EMPHYSEMA. An orbital fracture which communicates with a paranasal sinus or the nasal fossa allows air to enter the orbit, especially in blowing the nose. The distended lid presents a crackling sensation on palpation (emphysema).

LATERAL TEMPORAL ORBITAL APPROACH TO RETRO-OCULAR SPACE (KRÖNLEIN). The greatest diameter of the orbital entrance is transverse, and the eyeball, therefore, is farther from the lateral than from the upper and lower margins of the orbit. Hence the best mode of approach to the posterior portion of the globe and to the retro-ocular space is through the lateral (temporal) side. After division of the soft parts by a laterally concave incision sufficiently deep to expose the entrance into the orbit, the outer wall is resected. The periosteum is separated from the lateral orbital wall as far as the inferior orbital fissure, which is made the apex for the wedge of orbital wall mobilized. This wedge, with its muscle and cutaneous attachments, is forced backward, giving free access to the contents of the retrobulbar space, still partly covered by periosteum, which is split and retracted. If necessary, the external rectus muscle (p. 39) is divided near its tendinous insertion, and the dissection is continued to the apex of the orbit. After the surgical maneuvers have been carried out the osteoplastic flap is replaced, and the periosteum is sutured.

INTRACRANIAL APPROACH TO THE ORBIT FOR ORBITAL DECOMPRESSION (NAFFZIGER AND JONES). The operation of decompression of the orbit and the optic foramen was designed to give adequate space for the increased orbital content and the constricted optic nerve in progressive exophthalmos following thyroidectomy. The surgical procedure consists in reflecting bilateral frontal flaps, elevating the dura over the frontal lobe, unroofing the orbit and removing the superior portion of the optic foramen. Before operation, roentgen studies are made to determine the height and extent of the frontal sinuses and the projection of the ethmoid and frontal sinuses into the orbital plate. Views of the optic foramina reveal the immediate relation of the sphenoid sinuses to the orbital plate, so that the operation may be conducted in such a way as not to open these cells.

The frontal bone is exposed by a transverse incision from the temporal fossa on one side, across the frontoparietal region immediately behind the hair line, down to the temporal fossa on the opposite side. The scalp is dissected from the pericranium and is reflected forward, so that the entire frontal bone on both sides is exposed down to the frontal sinus. Bilateral frontal flaps then are fashioned, the hinge of each being the temporal muscle. A small ridge of bone is left in the midline to stabilize these flaps when they are replaced.

After the reflection of the bone flap the dura is elevated from the floor of the anterior cranial fossa. The stripping of the dura from the anterior fossa is carried back to the sphenoidal ridge and to the base of the anterior clinoid process. Mesially, the stripping is continued almost to the cribriform plate. The roof of the orbit then is opened and is removed by rongeur. The bone opening is carried anteriorly to the frontal sinus and laterally to the point where the orbital roof merges with the lateral wall of the skull. Posteriorly, it is continued to the sphenoidal ridge. The roof of the optic foramen and its superolateral margin are removed. The orbital contents bulge through the bone opening as it is enlarged. When the bone opening is complete, the orbital fascia is opened.

This approach may be utilized in operative procedures on any of the contents of the retro-ocular space.

PALPEBRAL AND CONJUNCTIVAL REGIONS

EYELIDS. The eyelids, or palpebrae, are upper and lower musculomembranous structures developed in front of the orbit as a protective mechanism to the eyeball (Figs. 34, 35, 38, 53). They protect the retina and brain from light which otherwise would create cortical images and maintain cerebral activity, and also through the winking reflex serve to protect the

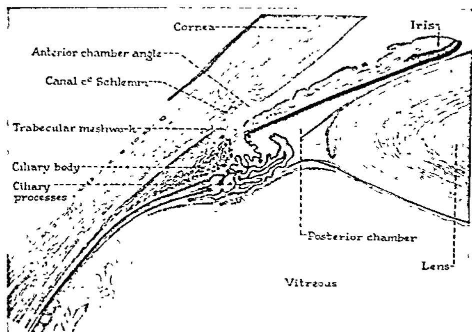


Fig. 40. CORNEA, IRIS, LENS, CHAMBERS AND RELATED PARTS OF THE EYE, SHOWN IN CROSS SECTION. (From Salzmann: Anatomy and Histology of the Human Eyeball, University of Chicago Press.)

closing the lids. In the event of nerve injury special measures must be taken to prevent desiccation and ulceration of the cornea from nonclosure of the lids. With central or brain palsy of the nerve root, the orbicularis oculi muscle functions because of its cross innervation. The levator palpebrae muscle is supplied by the oculomotor nerve, paralysis of which results in ptosis, or inability to lift the lid.

The *sensory innervation* of the lids is derived from the trigeminal nerve through its ophthalmic and maxillary divisions. The nonstriated fibers of the involuntary palpebral muscle are supplied by the *sympathetic nerves*. Stimulation of the cervical sympathetic chain causes a contraction in the smooth muscle in the lids, resulting in a slight spreading of the lids or an increase in size of the palpebral fissure. Resection of the cervical ganglia results in sinking in of the eyeball (enophthalmos), together with a slight ptosis and a contraction of the pupil. The latter condition is referred to as "Horner's syndrome."

Surgical Considerations

COMMON LID LESIONS. Chronic inflammatory enlargement of the meibomian (tarsal) glands, *chalazion*, is a common condition which develops in consequence of obstruction of the ducts, often brought about by chronic infection (Fig. 42). These lesions show a marked tendency to recurrence in groups. The affected glands usually are incised and curetted, since complete dissection is difficult.

Drooping of the lid, *ptosis*, is caused by insufficient development or paralysis of the levator palpebrae muscle, which, when extreme, disturbs vision by covering the pupil. An attempt is made to raise the lid by forced action of the occipitofrontal muscle, wrinkling the skin of the forehead and raising the brow. When the condition is bilateral, exposure of the pupil is favored by throwing the head backward. Ptosis also occurs in connection with paralysis of other muscles controlled by the oculomotor nerve. Not infrequently the nerve to the levator palpebrae muscle is injured in removal of tumors from the retro-ocular portion of the orbit (p. 59). When a ptosis appears to be permanent, it can be corrected surgically by shortening the levator, attaching it to the superior rectus (if intact) or producing adhesions between the levator and the frontalis muscle.

Trichiasis is a distortion of the eyelashes in which they are directed backward instead of forward to the extent that they rub against the cornea, mechanically irritating and injuring it (Fig. 43). The condition occurs with contractures of the palpebral conjunctiva and of the

(akinesis) to produce a temporary paresis and prevent "squeezing" of the lids during operation.

The *conjunctiva*, in its tarsal portion, is closely adherent to the tarsal plates, and from them is reflected over the anterior surface of the eyeball to form the bulbar portion. Both above and below, at the point of reflection, there is a loose fold or redundancy forming a cul-de-sac, the conjunctival fornix. The superior fornix sometimes is the seat of trachoma and should always be examined in trachoma suspects. The bulbar conjunctiva completely covers the eyeball in front and is attached loosely over the sclera. It is so thin that the white of the eye can be seen through it and, because of its elasticity, blood supply and loose attachment, is ideal for plastic operations.

VESSELS AND NERVES. The chief *arteries* of the eyelid are the superior and inferior palpebral branches of the ophthalmic artery. They run in loose tissue between the orbicularis muscle and the orbital septum. Laterally, they course from the mesial side of the orbit, anastomosing with the lacrimal, superficial temporal and transverse facial arteries, and forming an arch in each lid. The rich vascular anastomoses are of practical importance in the rapid healing of wounds in this region. The subconjunctival or retrotarsal *veins* drain into the ophthalmic veins. The *lymphatics* form pretarsal and retrotarsal networks which, for the most part, drain into the preauricular and parotid lymph glands.

The chief *motor nerve* of the region is the facial nerve to the orbicularis oculi muscle (Figs. 34, 35). It must be preserved, since the muscle plays the important sphincter role of

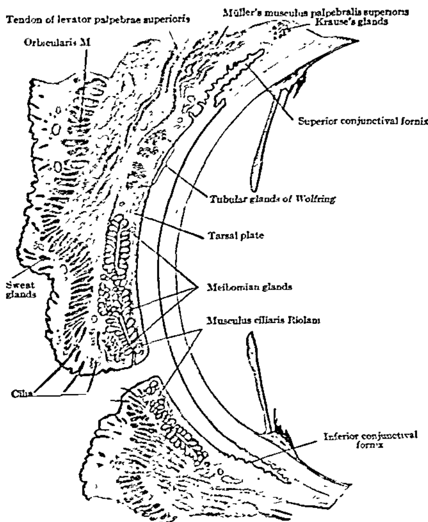


Fig. 39. PALPEBRAL AND ANTERIOR OCULAR REGIONS, SHOWN IN SAGITTAL SECTION
(From Gifford's Textbook of Ophthalmology, revised by Adler, 1957.)


Fig. 45.


Fig. 46.

Figs. 45, 46. COMMON LESIONS OF THE EYELIDS (*Continued*).
Fig. 45, Pterygium; Fig 46, hordeolum (stye) of both lids. (Marfaing.)

caustic substance introduced into the conjunctival sac between the lid and the globe, but may occur from a postoperative adhesion or from trachoma. It is anterior or partial when it extends like a bridge from the lid to the globe, leaving a free portion of conjunctiva corresponding to the fornix; it is posterior when only the fornix is involved, and complete when all the conjunctiva is affected.

A *pterygium* is a misplaced triangular fold of mucous membrane extending from either the mesial or lateral side of the bulbar conjunctiva to or over the cornea where its apex is attached (Fig. 45). The base spreads out and merges with the conjunctiva.

A *hordeolum*, or stye, is a circumscribed acute inflammation at the margin of the lid, caused by staphylococcal infection of one or more of the sebaceous follicles of the lashes (Zeiss' glands), and usually ends in suppuration (Fig. 46).

Foreign bodies in the conjunctival cavity usually adhere to the subtarsal sulcus of the upper lid and are removed easily after eversion of the lid. Removal of particles striking and lodging in the cornea is more difficult.

LACRIMAL APPARATUS

DEFINITION. The lacrimal apparatus is comprised of the lacrimal gland and its intrinsic ducts, the two lacrimal ducts, the lacrimal sac and the nasolacrimal duct.

LACRIMAL GLANDS AND THEIR DUCTS. The lacrimal gland is a small, oblong body situated in the upper lateral part of the orbit, deep to the upper lid and adherent to the orbital fat lying behind it (Fig. 34). The aponeurosis of the levator palpebrae muscle divides it into two parts or lobes, orbital and palpebral.

The *orbital portion*, or *superior lacrimal lobe*, is the longer and is located in and fixed to a depression in the orbital plate of the frontal bone. Behind, it rests on the outer part of the tendon of the levator palpebrae muscle; in front, it lies against the orbital septum, through which easy access is gained for removal of this portion of the gland.

The *palpebral portion*, or *accessory lobe*, is much smaller and joins the superior lobe behind. It extends beyond the orbital margin, where it lies mainly on the palpebral conjunctiva, to which it is adherent and through which its ducts open. The openings of the ducts of both lobes may be seen by everting the upper lid. The lacrimal secretion is a clear, salty, alkaline fluid, and the gland usually secretes just enough to moisten the eyeball. Psychic stimulation or irritation of the eye or nose increases the flow. The lubrication of the margins of the lids prevents the escape of tears from the conjunctival cavity.

TEAR PASSAGES. By movement of the lids, tears are collected into the lacus lacrimalis at the medial angle of the eye. From here, by capillary, they pass through the two small lacrimal puncta into the lacrimal ducts, and thence into the lacrimal sac. From the sac they are conveyed into the nasal fossa by the nasolacrimal duct (Fig. 34). A lesion in any segment of the lacrimal paths may produce excessive flow of tears (epiphora).

The *lacrimal puncta*, one on each lid, are minute orifices leading into the two small *lacrimal ducts* or canals. These canals, each about

tarsal plates in trachoma, and is a complication of entropion.

Entropion is the turning in of the margin of the lid with its lashes, as a result of scar changes in the conjunctiva or tarsal plate or of spasm of the palpebral portion of the orbicular muscle. It occurs usually in the lower lid, and the trichiasis produced irritates and injures the cornea.

Ectropion is an eversion of the lid with more or less exposure and irritation of the palpebral conjunctiva, which becomes hypertrophied and reddened (Fig. 44). It results from cicatricial contractions, chronic conjunctivitis and, in elderly people, from a laxity of the skin and orbicular muscle. An excessive flow of tears (epiphora) aggravates the condition if the eye is wiped downward habitually. In advanced ectropion the cornea may suffer from exposure occasioned by imperfect approximation of the lids.

Blepharospasm, or spasmodic closing of the lids, is caused by tonic or clonic contractions of the orbicular sphincter. The tonic form occurs from the irritation of foreign bodies, corneal affections and local inflammatory conditions, or from any excitation of exposed sensory terminal filaments of the trigeminal nerve. The clonic form is manifested by fibrillary twitching of the palpebral portion of the orbicular muscle and, although not serious, is annoying and unduly alarming to the patient.

Bulbar conjunctivitis involves the globe, and *tarsal conjunctivitis* the lids; either may be acute or chronic. The cause may be bacterial (gonococcus, pneumococcus, Koch-Weeks bacillus, Morax-Axenfeld bacillus, staphylococcus, and others), chemical, mechanical, allergic or occasionally eyestrain. Treatment is directed largely toward removal of the cause.

Trachoma is a chronic contagious form of conjunctivitis accompanied by conjunctival hypertrophy into follicular masses which undergo cicatricial changes. Adequate and long-continued treatment lessens the menace of conjunctival scar formation. Trachoma in its most chronic form may progress to blindness.

A *symblepharon* is formed by the adherence of two superimposed raw surfaces resulting from destructive change occurring in corresponding parts of the palpebral and ocular conjunctiva. It is caused generally by some

Fig. 41.



Fig. 42.





Fig. 43.



Fig. 44.

Figs. 41 to 44. COMMON LESIONS OF THE CONJUNCTIVA AND THE EYELIDS.

Fig. 41, Subconjunctival hemorrhage; Fig. 42, chalazion; Fig. 43, trichiasis; Fig. 44, ectropion. (Marfaing.)



Fig. 45.



Fig. 46.

Figs. 45, 46. COMMON LESIONS OF THE EYELIDS (*Continued*).
Fig. 45, Pterygium; Fig. 46, hordeolum (stye) of both lids. (Marfaing.)

caustic substance introduced into the conjunctival sac between the lid and the globe, but may occur from a postoperative adhesion or from trachoma. It is anterior or partial when it extends like a bridge from the lid to the globe, leaving a free portion of conjunctiva corresponding to the fornix; it is posterior when only the fornix is involved, and complete when all the conjunctiva is affected.

A *pterygium* is a misplaced triangular fold of mucous membrane extending from either the mesial or lateral side of the bulbar conjunctiva to or over the cornea where its apex is attached (Fig. 45). The base spreads out and merges with the conjunctiva.

A *hordeolum*, or stye, is a circumscribed acute inflammation at the margin of the lid, caused by staphylococcal infection of one or more of the sebaceous follicles of the lashes (Zeiss' glands), and usually ends in suppuration (Fig. 46).

Foreign bodies in the conjunctival cavity usually adhere to the subtarsal sulcus of the upper lid and are removed easily after eversion of the lid. Removal of particles striking and lodging in the cornea is more difficult.

LACRIMAL APPARATUS

DEFINITION. The lacrimal apparatus is comprised of the lacrimal gland and its intrinsic ducts, the two lacrimal ducts, the lacrimal sac and the nasolacrimal duct.

LACRIMAL GLANDS AND THEIR DUCTS. The lacrimal gland is a small, oblong body situated in the upper lateral part of the orbit, deep to the upper lid and adherent to the orbital fat lying behind it (Fig. 34). The aponeurosis of the levator palpebrae muscle divides it into two parts or lobes, orbital and palpebral.

The *orbital portion*, or *superior lacrimal lobe*, is the longer and is located in and fixed to a depression in the orbital plate of the frontal bone. Behind, it rests on the outer part of the tendon of the levator palpebrae muscle; in front, it lies against the orbital septum, through which easy access is gained for removal of this portion of the gland.

The *palpebral portion*, or *accessory lobe*, is much smaller and joins the superior lobe behind. It extends beyond the orbital margin, where it lies mainly on the palpebral conjunctiva, to which it is adherent and through which its ducts open. The openings of the ducts of both lobes may be seen by everting the upper lid. The lacrimal secretion is a clear, salty, alkaline fluid, and the gland usually secretes just enough to moisten the eyeball. Psychic stimulation or irritation of the eye or nose increases the flow. The lubrication of the margins of the lids prevents the escape of tears from the conjunctival cavity.

TEAR PASSAGES. By movement of the lids, tears are collected into the lacus lacrimalis at the medial angle of the eye. From here, by capillary, they pass through the two small lacrimal puncta into the lacrimal ducts, and thence into the lacrimal sac. From the sac they are conveyed into the nasal fossa by the nasolacrimal duct (Fig. 34). A lesion in any segment of the lacrimal paths may produce excessive flow of tears (epiphora).

The *lacrimal puncta*, one on each lid, are minute orifices leading into the two small *lacrimal ducts* or canals. These canals, each about

1 cm. long, run in the skin mesial to the posterior external wall of the lacrimal sac, into which they empty through a common canal which is covered by the mesial palpebral ligament.

The *lacrimal sac*, 1 to 1.5 cm. in length, is the expanded upper part of the tear passage lying at the medial margin of the orbital septum. It is roofed completely by a specialized layer of periorbita, the fascia lacrimalis. The mesial palpebral ligament and the inner tendon of the orbicularis oculi muscle lie in front of and against it, dividing it into two portions, one above and one below. The lower part, which is accessible surgically, may become distended and bulge forward. The landmarks for the location of the sac are the mesial palpebral ligament and the anterior lacrimal crest, which are brought into relief by drawing the lids laterally. Since the sac lies in a fossa of the lacrimal bone in intimate relation with the anterior ethmoid cells, inflammation of the sac, dacryocystitis, may follow upon or cause ethmoiditis.

The *nasolacrimal duct* is the downward continuation of the lacrimal sac, draining the tears into the inferior nasal meatus about 1 cm. behind the anterior tip of the inferior turbinate bone (Fig. 34). It is contained in a bony canal formed largely by the maxilla, which brings it into close relation with the maxillary sinus. Continuity of the duct and nasal mucous membrane explains the frequency of disease extending from the nose to the lacrimal passages.

Surgical Considerations

DACRYOCYSTITIS. Disease of the lacrimal gland itself is rare except for hypofunction with resultant drying of the cornea (keratoconjunctivitis sicca), but involvement of the tear-conducting passages (dacryocystitis) is common. The cause of inflammation of the tear sac usually is obstruction in the nasolacrimal duct, the consequence of infection in the nasal fossa or paranasal sinuses, or in infants the result of a congenital membranous obstruction in the nasolacrimal duct. Epiphora, or increased lacrimation, is a prominent symptom in all diseases of the tear-conducting apparatus. It may be caused by foreign bodies, conjunctivitis, irritating vapors or nasal disease.

PROBING OF THE LACRIMAL PASSAGES; EXTIRPATION OF THE SAC. The normal lacrimal duct admits a probe 3.5 mm. in diameter, which is passed mesially through the lower punctum. When it reaches the medial wall of the sac, which is recognized by the resistance offered by the lacrimal bone, the probe is raised so that its lower end is directed toward the sulcus between the nose and the cheek, and is pushed gently downward until it enters the nose. Should this measure fail to relieve longstanding obstruction, a more radical course is advised, such as extirpation of the lacrimal sac, or establishment of a communication between the sac and the middle nasal meatus (dacryocystorhinostomy or Toti's operation).

For the extirpation of the lacrimal sac, an incision about 2 cm. long is made through the skin and underlying tissue along the anterior orbital margin inferior to the mesial palpebral ligament. When the sac is exposed, it is separated from the periosteum of the lacrimal fossa, the upper extremity is freed, the ducts are divided, and the sac is excised as low as possible in the nasolacrimal duct.

OCULAR GLOBE

The ocular globe, or eyeball, with its wall and contents, occupies that part of the orbit anterior to Tenon's capsule, or fascia of the bulb (Figs. 53, 54). The wall is made up of three concentric membranes. The external or fibrous membrane is the sclera, transformed in front into the transparent cornea. The middle or vascular layer is the choroid, differentiated anteriorly into the ciliary body and a muscular diaphragm, the iris. The inner or nerve layer, the retina, is differentiated highly over the posterior part of the globe (Figs. 47, 49, 55).

The contents of the globe are the transparent media of the eye: the crystalline lens directly behind the iris, the cornea, the aqueous humor filling the space between the lens and the cornea, and the vitreous humor between the lens and the retina (Figs. 47, 49). These refracting media are so constituted and placed that normally they converge rays to a focus on the retina.

Focusing depends upon the depth of the anteroposterior diameter of the eyeball and the distance traveled by the rays reaching the retina. Under abnormal conditions the anteroposterior diameter of the eye may be lengthened or shortened. When shortened, the refractive media are incapable of sufficient convergence, and the rays reach a focus behind

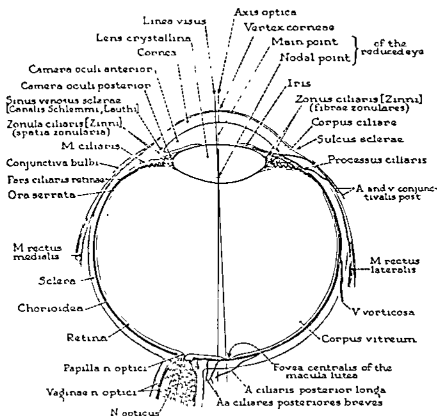


Fig. 47. SECTION THROUGH THE RIGHT EYE; SCHEMATIC.

(Anson: An Atlas of Human Anatomy.)

the retina. This constitutes the hypermetropic eye. To bring about a retinal focus, the converging apparatus must be supplemented by a convex lens. When the anteroposterior diameter is greater than normal, the rays come to a focus in front of the retina, constituting the myopic eye. The refractive media in this condition overconverge and require a concave lens to lessen the convergence and to bring the focus on the retina.

WALLS OR TUNICS OF THE GLOBE

FIBROUS OR SCLEROCORNEAL TUNIC. The sclera behind and its specialized cornea in front constitute the outer tunic of the globe. The SCLERA is a thick, resistant, nondistensible membrane, thickest posteriorly, giving form to the eye and affording attachment to the ocular muscles (Fig. 47). The "white of the eye" is the anterior portion of the sclera seen through the transparent ocular conjunctiva. Rupture of the eyeball usually occurs where the sclera is thinnest, near the sclerocorneal junction.

Where the optic nerve penetrates the globe, the fibrous sheath of the nerve blends with the outer part of the sclera. The sclera is pierced for the passage of the nerve bundles, creating a sievelike portion designated the *lamina cribrosa*. About the entrance of the nerve are several minute openings carrying the ciliary nerves and arteries. The *ciliary arteries* are derived from the numerous posterior ciliary branches of the ophthalmic artery (Fig. 48). The long ciliary branches run forward between the choroid and the sclera to supply the iris and ciliary region, and the short ciliary arteries terminate in the choroid. The *veins* converge to form four or five main trunks, the venae vorticosae, which pierce and leave the sclera midway between the cornea and the optic nerve to join the ophthalmic veins.

The CORNEA is continuous with the opaque sclera and, although made up of the same connective tissue, is transparent. It forms the anterior fifth or sixth of the fibrous tunic of the globe and is thinnest in the center and thickest at the periphery. It contains no trace of blood vessels save at its extreme periphery, but, when affected by disease, may develop opacities as a result of infiltration and scarring (later)

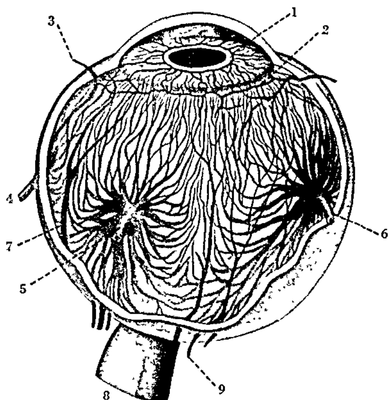


Fig. 48. DISSECTION OF THE BLOOD VESSELS OF THE OCULAR BULB.

Key to numbered leaders: 1, lesser arterial circle; 2, major arterial circle; 3, anterior ciliary artery; 4 to 6, vorticose veins; 7, long posterior ciliary artery; 8, optic nerve; 9, short posterior ciliary artery. (From Gifford's Textbook of Ophthalmology, revised by Adler, 1957.)

with invasion of blood vessels from the conjunctival (superficial) or ciliary (deep) systems. The line of junction between the cornea and sclera is the *limbus*, close to which incisions are made for operations on the structures directly posterior, the iris and lens. The *posterior lamina* of the cornea (Descemet's membrane) is a thin, highly elastic layer behind the proper substance of the cornea. At the sclerocorneal junction this membrane splits into bundles of fine interlacing fibers which form the *pectinate ligament*, connecting the sclera with the root of the iris. The spaces between these trabeculated bundles are known as the *spaces of the angle of the iris* (spaces of Fontana). They are lined with endothelium prolonged from the endothelium of the anterior chamber of the globe (Descemet's membrane). Anterior to the sclerocorneal junction in the sclerocorneal layer is the *venous sinus of the sclera* (canal of Schlemm).

That area of the anterior chamber where the sclerocorneal margin, iris and pectinate ligament meet is the filtration angle of the iris, often called the *iris angle* or *iridocorneal angle.* It forms the principal exit for the intraocular fluids, and its blockage causes their retention. The normal flow of intraocular fluid is from the anterior chamber to the venous sinus of the sclera by filtration through the spaces of the iris angle and thence into the anterior ciliary veins. Blockage of the iris angle is a consequence of embarrassment in the circulation between the anterior and posterior aqueous chambers, adhesions between the iris and the cornea (peripheral anterior synechiae) as a result of iritis, or of pushing forward of the vitreous chamber and lens with venous congestion, subsequent swelling of the ciliary body, and pushing of the periphery of the iris against the sclerocorneal junction.

In *glaucoma*, a condition marked by increased intraocular pressure, the added tension depends upon a disturbed relationship between intraocular secretion and excretion. The obstruction to the escape of intraocular fluid is thought to be effected at the angle of the anterior chamber (iris angle) by pressure of the peripheral portion of the iris and of the congested and swollen ciliary processes against the sclero-

corneal junction. Later, it may be caused by an adhesive inflammation of the opposed surfaces with proliferation of the endothelium of Descemet's membrane and that of the iris.

VASCULAR OR IRIDO-CILIARY-CHOROIDAL TUNIC (UVEAL TRACT). The irido-ciliary-choroidal layer is composed of the iris, ciliary body and choroid, and extends from the pupil to the optic nerve (Fig. 47). The choroid and ciliary portions are in contact with the sclera, while their termination, the iris, turns sharply inward and floats in the aqueous humor between the cornea and lens. It divides the space in front of the lens unequally into the anterior and posterior chambers (cameras) of the eye.

The CHOROID is the part of the uveal tract lining the posterior portion of the eye. It is the nourishing tunic, comprised essentially of blood vessels (Figs. 47, 48). These vessels are visible in ophthalmoscopic examination in blond persons with transparent retinas. They produce the red background in the fundus of the eye, against which the retinal vessels stand out in bold relief. Diseases of the circulatory system, particularly syphilis and arteriosclerosis, often are manifested in the choroid. The presence of pigment cells in this layer gives rise to the pigmented malignant melanoma.

The CILIARY BODY connects the choroid to the circumference of the iris. The line of junction between it and the retina anteriorly is the *ora serrata*, in front of which arise the ciliary processes, about seventy in number. Suspensory ligaments are attached to these meridional processes and to the periphery of the lens. When the ciliary muscle contracts, it draws its processes and the choroid forward, thus relaxing the ligament suspending the lens, and allowing the lens to bulge and assume a more convex shape. This relaxation and contraction controls the convexity of the lens and, therefore, its refracting power, making it the chief agent in accommodation.

The IRIS is the anterior segment of the vascular tunic and is visible through the cornea. It is a thin, delicate, contractile membrane placed as a circular diaphragm in front of the lens, presenting an aperture of variable size called the *pupil*. This membrane partially divides the space between the lens and cornea into two parts, the *anterior* and *posterior chambers* (cameras) of the eye, which are filled by aqueous humor. The unstriped muscle fibers of the iris are arranged in two sets, a circular sphincter set, contraction of which narrows the pupil, and a radial set, which dilates it. The pupillary margin of the iris lies on the anterior capsule of the lens, from which it derives much support.

When completely dilated, the iris hangs free in the space in front of the lens. Action of the dilator and sphincter muscles regulates the amount of light admitted to the interior of the eye and cuts off the marginal rays which otherwise interfere with the sharpness of the retinal image. The sphincters are supplied by the *oculomotor nerve* and the dilators by the *sympathetic nerves*. The pigment cells of the iris give it color.

The peripheral margin of the iris is derived from the anterolateral portion of the ciliary body, and is attached in front to the cornea by the pectinate ligament. The iris is torn easily from this origin and attachment (*iridodialysis*) by trauma to the globe. The iris frequently protrudes through perforating wounds of the cornea, and excision of the prolapsed piece (*iridectomy*) is necessary.

The vascularity of the iris renders it peculiarly liable to inflammatory changes, and infection readily spreads to it through its attachments. Since the iris and choroid are part of the same vascular membrane, inflammation set up in the choroid tends to involve the iris. Inflammatory changes cause the membrane to become swollen and the pupil small and sometimes covered by exudate (*occlusio pupillae*). With the pupillary margins in actual contact with the lens capsule, and especially in severe iritis, adhesions may form between the opposed parts (*posterior synechia*). If the synechia formation is extensive, it may seal the pupil completely posteriorly, thereby blocking the only communication between the posterior and anterior chambers and leading directly to a rise in intraocular tension (*secondary glaucoma*). An adhesion between the iris and the cornea is an *anterior synechia*.

RETINAL OR NERVE TUNIC. The retina is an extension and expansion of the fibers of the optic nerve into a specialized apparatus for the reception of visual stimuli (Figs. 40, 49, 50). It lies between the membrane containing the vitreous humor (hyaloid membrane) internally and the choroid externally, and extends forward almost to the ciliary body, where it presents a wavy line, the *ora serrata*. Beyond this line the membrane loses its nerve cells, be-

N. opticus
A. centralis retinae
V. centralis retinae
Retina
Choroidea
Sclera
Pars optica retinae
Pars ciliaris retinae
Processus ciliaris
Angulus iridis
Zonula ciliaris (Zinni)
Camera oculi anterior
Camera oculi posterior
Lens crystallina
Iris
Cornea
Sinus venosus sclerae
Circulus arteriosus major
Processus ciliaris
M. ciliaris
Ora serrata

Fig. 49. OCULAR GLOBE IN SAGITTAL SECTION.

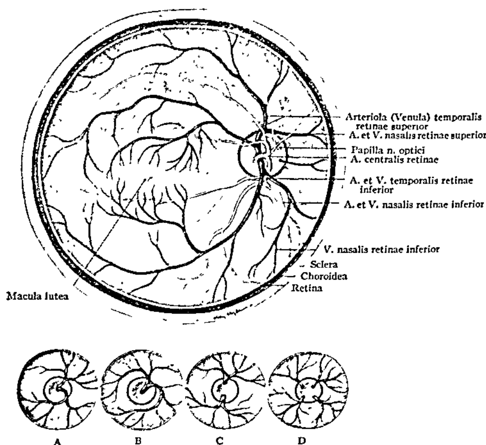


Fig. 50. NORMAL RIGHT EYEGROUND AND TYPES OF BRANCHES OF THE CENTRAL VEIN OF THE RETINA.

A, Bifurcation of the retinal vein at the center of the optic disk. *B*, Bifurcation at the margin of the disk. *C*, Bifurcation before emerging from the disk. *D*, Branching of the central vein of the retina before emerging from the optic disk. (After Testut and Jacob.)

comes thin, and is extended to the ciliary body. It is unattached to the choroid save at the entrance of the optic nerve and at the ora serrata, which accounts for its easy separation from the choroid in severe trauma to the head or eye, in intraocular tumors, in diseases of the vitreous body and in high myopia. The retina is transparent under normal conditions because the optic nerve fibers composing it lose their opaque myelin coverings on entering the ocular globe. This transparency prevents its visibility, but renders visible the subjacent vascular choroid and the overlying pigment epithelium seen as the red background of the eye in ophthalmoscopic examination.

In the retina are three intrinsic elements of the greatest clinical and pathologic importance, since in and about them the most important lesions in the background of the eye develop. These are the vessels of the retina, the point of entrance of the optic nerve (optic disk), and the point of clearest vision (macula). Their observation is the cardinal object of ophthalmoscopic examination.

The *central artery* of the *retina*, a branch of the ophthalmic artery, is not in direct communication with collateral vessels except at the entrance of the optic nerve (Figs. 49 to 51). Accompanied by corresponding veins, it pierces the optic nerve about 2 cm. from the globe and runs within it to enter the retina about the middle of the optic disk (Figs. 50, 51). The branches of the artery are terminal, and permanent plugging of the parent trunk brings about extinction of the retinal arterial system, resulting in complete blindness. On reaching the retina, the artery divides into ascending and descending branches of variable number, shape and location. These vessels, because of the transparency of the retina, are perfectly visible through the ophthalmoscope (Fig. 50). The opportunity of studying blood vessels *in situ* with adequate illumination under ideal optical conditions is offered nowhere else in the body. Each artery presents a double outline, appearing as two bold red lines separated by a lighter interval.

The *veins* are broader and more homogeneous than the arteries. They empty into the ophthalmic veins which, in the retro-orbital

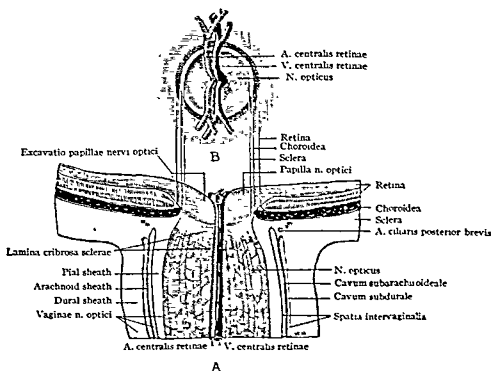


Fig. 51. DIAGRAM OF THE OPTIC DISK OR PAPILLA TO CORRELATE ITS STRUCTURES WITH OPHTHALMOSCOPIC FINDINGS.

A, Sagittal section through the optic nerve at its entrance into the eyeball; *B*, structures seen on sagittal section projected on the disk as viewed ophthalmoscopically. (After Testut and Jacob.)

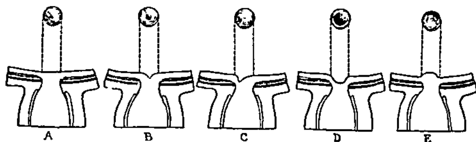


Fig. 52. VARIATIONS IN THE CONTOUR OF THE OPTIC DISK AS SEEN IN SAGITTAL SECTIONS.

The variations in contour are projected into ophthalmoscopic images. *A*, Flat disk (within physiologic limits). *B*, Central depression or cupping (within physiologic limits). *C*, Eccentric depression (within physiologic limits). *D*, Excavation (seen in glaucomatous conditions). *E*, Protrusion (seen in increased intracranial pressure). (Testut and Jacob.)

region, form the cavernous sinus (Figs. 13, 16). Engorgement of these veins naturally occurs in venous stasis accompanying increased intracranial pressure. Lesions of the retinal vessels are manifested by retinal hemorrhages and sclerotic changes in the vessels themselves.

About 3 mm. to the inner side of the posterior part of the eye is a conspicuous, pale, round, opaque area, the *optic disk* or *papilla*, which marks the entrance of the optic nerve into the eyeball (Figs. 51, 52). The term "papilla" was given by early authors under the erroneous impression that it represented a projection into the interior of the eye. In the normal state it is flat, lying in the same plane as the retina, or having a central or eccentric depression. This depression, the *physiologic cup* or excavation, marks the point of divergence of the entering optic nerve fibers and is the common entry of the retinal vessels. Gray dots in its depth indicate lacunae in the lamina cribrosa through which the separate funiculi of the optic nerve enter. While the nerve fibers normally lose their myelin sheaths before passing through the lamina cribrosa, the presence of myelinated fibers about the disk is not unusual. They have the appearance of glaring white tufts of cotton. The normal level of the optic disk is swollen and elevated in choked disk and optic neuritis, and depressed in nerve atrophy and glaucoma.

In the axis of the globe the surface of the retina presents a yellow spot, the *macula lutea*, or area of most distinct vision. It is about 1 to 2 mm. in diameter and has in its center a small depression, the *fovea centralis*, or spot of most distinct vision. Lesions in this locality are serious, bringing about loss of central vision.

Surgical Considerations

INFLAMMATION, STAPHYLOMA AND RUPTURE OF THE SCLERA. Inflammation of the sclera may be superficial or deep. If deep, it may extend to subjacent and contiguous parts and cause a thinning of the wall and bulging of the sclera, resulting in *scleral staphyloma*. When the globe is *ruptured* by violence, the scleral coat usually yields, and rents occur in the thinnest portion a little behind the cornea. The sclera sometimes is ruptured when the conjunctiva remains intact, and the lens may escape through the subconjunctival rent.

DISEASES OF THE CORNEA. Inflammation of the cornea, *keratitis*, may be superficial or deep, involving only the epithelium on the anterior or free surface, or involving the corneal tissue proper. In interstitial keratitis the numerous laminae of the cornea and their freely anastomosing lymph channels are affected, with resulting effusion into the lymph vessels and consequent haziness and loss of transparency. This haziness may or may not be followed by complete resorption; permanent opacity results when resorption fails.

A *corneal ulcer* is caused by infection of a portion of the cornea followed by suppuration and loss of substance of the tissue involved. Connective tissue repair of deep ulcers produces a scar and consequent *opacity*. The opacity following corneal ulcers or wounds may resemble a puff of smoke (*nebula*) or be pearly-white (*leukoma*). A deep ulcer sometimes gives rise to inflammation in the conjunctiva and iris; a virulent process may destroy the eye.

Arcus senilis is an opaque, whitish ring or crescent, appearing at the periphery of the cornea within the sclerocorneal junction, usually in people of advanced age. It results probably from fatty degeneration of the corneal tissue, the changes occurring in the layers just deep to the anterior elastic membrane.

Since the cornea is a segment of a flattened sphere (ellipsoid), there is a slight difference

in the refraction of the two principal meridians, the vertical curvature being greater than the horizontal. *Astigmatism* is a condition of the eye in which the refraction from these diameters or meridians varies considerably because of changes or differences in the curvature of the cornea, with or without shortening or lengthening of the anteroposterior diameter of the eyeball. It is, as a rule, congenital, but may be acquired from corneal changes produced by inflammation, injury or operation.

Diseases of the Iris. Inflammation of the iris from any one of a variety of infections, including syphilis and tuberculosis, is associated so frequently with inflammation of the ciliary body that most cases called iritis really are *iridocyclitis*. The iris, when inflamed, appears dull and swollen, and the pupil small, irregular, and sluggish in its reaction to light; there may be pus in the aqueous chamber, a lesion which is called *hypopyon*. As a consequence of this infection, adhesions between the iris and the lens capsule (synechia) may develop (p. 50).

Lesions of the Ciliary Body, and Uveitis. The conception of the choroid, ciliary body and iris constituting a continuous vascular tunic, the uveal tract, explains why an inflammation of the individual elements frequently involves the whole tract, *uveitis*. Inflammation of the ciliary body, *cyclitis*, when combined with infection of the iris, is *iridocyclitis*.

Since the ciliary region is an extensive vascular anastomotic area about the cornea, infections can pass directly from the ciliary region to the other elements of the eye, particularly the vitreous humor. An acute, purulent cyclitis occurring immediately after injury may involve all the structures of the eye (*panophthalmitis*), and the eye must be enucleated if not controlled by intravitreal injection of antibiotics. Chronic plastic iridocyclitis in one eye following penetrating injuries sometimes causes destructive inflammation in the sound eye (*sympathetic ophthalmia*). A blind, shrunken eye, resulting from either injury or operation, should be enucleated to preclude the development of the same dread complication.

Diseases of the Choroid. In many instances disease involving the choroid affects the retinal coats, *chorioretinitis*. In exudative *choroiditis* the decrease in the field of vision is in proportion to the extent of the exudative process. Absorption of the exudate leaves patches of choroidal atrophy, evidenced by white areas where the sclera shows through. Central vision is unimpaired if the macula escapes. If a retinal vessel passes unchanged through a patch of exudate, the destructive process probably has occurred in the choroid; if the outline of the vessel is blurred, the lesion also involves the retina.

Retinopathy refers to changes in the retina (exudates, deposits, hemorrhages), usually on a vascular basis. True inflammation of the retina, except as a chorioretinitis, does not exist. All the objective evidences of involvement of the retina are ophthalmoscopic; there are no external signs. Diminished visual acuity may result and perception be inaccurate as to the size and shape of objects, things appearing smaller than they really are, *micropsia*, or larger, *macropsia*. Ophthalmoscopic examination reveals whitish or pigmented patches which represent retinal exudate and hemorrhage.

The optic disk, the extension and only exposed region of the brain, is studied ophthalmoscopically for evidence of pathologic change in the brain proper. In inflammation of the disk, *optic neuritis* or *papillitis*, the nerve head presents characteristic signs. In addition to or independent of inflammatory signs, a marked edema of the disk may appear so that the swollen nerve head protrudes into the vitreous, a condition of *choked disk*, or *papilledema*. Full-blown papilledema, and the gradations leading to this condition, offer important evidence of increased intracranial pressure and are present in such intracranial disturbances as abscess, hydrocephalus, aneurysm and brain tumor. The recognition of optic atrophy is important from the visual standpoint and from the underlying systemic disease. Frequently glaucoma is unsuspected until discovered by ophthalmoscopic examination.

Detachment of the Retina. The retina not infrequently is torn as a result of trauma, and the resulting detachment causes blindness in the corresponding field of vision. The operation to reattach the retina opens a new field in ophthalmic surgery and offers a chance for permanent cure of a condition heretofore incurable. Multiple electropunctures of the sclera are made, each of which results in a minute focus of exudative choroiditis. Adhesions then develop which bind the previously separated retina to the choroid. In cases in which preoperative bed rest does not permit the retina

to return to near its normal position a scleral resection, with or without insertion of a polyethylene tubing, may be performed to shorten the sclera. The amount of restitution of vision depends on the condition of the retina before detachment and upon the duration of the detachment.

TRANSPARENT OR REFRACTING MEDIA

In addition to the cornea, the media which focus the rays entering the pupil are the aqueous and vitreous humors and the muscle-controlled lens suspended between them.

ANTERIOR OR AQUEOUS CHAMBER AND THE AQUEOUS HUMOR. The space between the cornea and lens, the anterior compartment of the eye, is filled with transparent aqueous humor (Figs. 39, 47, 49). The iris diaphragm subdivides this space into anterior and posterior cameras: that between the iris and cornea, the anterior; that between the iris and lens with its suspensory ligament, the posterior. With the iris in actual contact with the lens, the posterior camera is only an angular interval, triangular in cross section, between the iris, ciliary processes, suspensory ligament of the lens, and the lens periphery. The chambers communicate by the pupillary orifice.

The mode of formation of the aqueous humor and its manner of filtration are exceedingly important in relation to ocular tension (p. 50). This transparent fluid is secreted into the aqueous space by blood vessels of the ciliary processes. The collection of excess aqueous fluid is absorbed into the *iris angle spaces* (of Fontana) in the pectinate ligament, and from there filters into the circular venous sinus of the sclera (*canal of Schlemm*) (p. 50). Through the canal of Schlemm and the ciliary veins anastomosing with it, the aqueous humor leaves the eye. The required or physiologic tension in the globe probably is maintained by regulation of secretion and absorption of the fluid.

Obstruction to the filtration space about this angle renders escape of fluid difficult and brings about the grave accidents consequent upon increased intraocular tension. When the pupil is dilated, the periphery of the iris tends to encroach on the iris angle and render fluid passage difficult. Giving a pupil-dilating drug, such as atropine, in conditions of increased tension may precipitate glaucoma.

POSTERIOR OR VITREOUS CHAMBER AND THE VITREOUS HUMOR. The vitreous body is a transparent substance composed of semisolid connective tissue which occupies the vitreous compartment of the eye, the posterior four fifths of the bulb. The vitreous body rarely is involved by ocular disease, but may be affected secondarily by inflammation in adjacent parts. Its connective tissue cells occasionally produce shadows on the retina, *muscae volitantes*.

CRYSTALLINE LENS. The most important refracting medium of the eye, the crystalline lens, lies between the iris and the vitreous body, and separates the aqueous and vitreous cavities (Figs. 40, 47). It is a biconvex, transparent, colorless body enclosed by a thin, transparent hyaloid capsule, and lies within the circle formed by the ciliary processes, where it is held in position by its suspensory ligament. The convex surfaces, particularly the anterior, are constantly changing to aid in the focusing of rays from near or distant objects upon the retina.

The substance of the lens is seen best in elderly subjects in whom the lens nucleus takes on a change of color and consistency, clearly differentiating it from the cortical substance. The resulting gray reflex must not be confused with cataract. The sclerosing process begins in childhood; about the age of twenty-five a distinct nucleus is visible. After sixty years the lens becomes almost entirely nucleus. The inability of the sclerotic lens of middle life to change its shape accounts for the loss of the power of accommodation.

The circumference of the lens is fixed to the extremities of the ciliary processes by a system of fine, transparent radial fibers, the *suspensory ligament* or *ciliary zonule*. The lens is subject to injuries, dislocations and senile changes.

The function of the lens is performed by virtue of its elastic structure, whereby the convexity of its surfaces is changed promptly so that the rays are focused to form a perfect image on the retina. The ability of a lens to change its refractive power for objects at various distances is the *power of accommodation*. The change in the shape of the lens, affecting its anterior curvature chiefly, is produced by the action of the ciliary muscle tensing or relaxing the ciliary processes to which the suspensory ligament is attached. The ciliary muscle, by pulling the ciliary processes and the attached ciliary zonule forward, relaxes the

ligament and allows the lens to become more convex. Loss of elasticity in the lens reduces the power of accommodation, a condition termed *presbyopia*. With changes in the lens in middle age, power of accommodation is insufficient to permit exact vision, and the patient is obligated to supplement the diminished power with convex lenses. In *hypermetropia*, in which the eyeball is short and rays attain their natural focus behind the retina, effort of accommodation of the lens must be exerted continually to bring about retinal focus and clear vision. This accounts for the symptoms of eyestrain prevalent in uncorrected hyperopia.

Errors in refraction, particularly astigmatism, are responsible for a great variety of symptoms usually referred to the head. They are relieved, for the most part, by corrective lenses, together with suitable medical measures. It cannot be emphasized too strongly that refraction is essentially a medical problem.

Surgical Considerations

INJURIES TO THE LENS. The lens is loosened and displaced easily from the suspensory ligament and may make its way anteriorly into the aqueous compartment or posteriorly into the vitreous. The lens, if displaced into the aqueous humor, may be removed through a corneal incision. If dislocation takes place into the vitreous humor, glaucoma usually ensues. In scleral rupture the lens may escape from the globe and lie just deep to the conjunctiva.

CATARACT. When the lens capsule is wounded, aqueous humor is imbibed by the lens fibers, which, in consequence, swell and become opaque, forming a traumatic cataract. In cataract of any etiology some portion of the lens or all of it becomes the seat of opacity. Location of the opacity in either the *cortical* or *nuclear* substance establishes one basis for cataract classification.

TENON'S CAPSULE (FASCIA OF THE BULB)

FASCIA OF THE BULB. The fascia of the bulb, or Tenon's capsule, is a loose, frontally disposed membrane surrounding the posterior part of the eyeball and so placed as to partition the globe from the rest of the orbit (Figs. 53, 54). It is derived from the connective tissue of the structures of the orbit and from the periosteum about the orbital margin. It furnishes tubular sheaths to the orbital muscles as they attach to the globe, separates the globe from the orbital fat, and forms an articular socket which permits free movement of the eyeball.

The surgical importance of the fascia lies in *its action as a barrier to the spread of infection* or hemorrhage between the eyeball and the retro-ocular space, and its efficacy as a socket for a prosthesis (artificial eye) after enucleation of the eyeball.

FASCIAL EXPANSIONS. Where the internal and external rectus muscles perforate the fascia, strong capsular expansions spread to the inner and outer walls of the orbit, limiting the play of the recti muscles and acting as *inner* and *outer check ligaments*. The check ligaments are important surgically in that they limit the

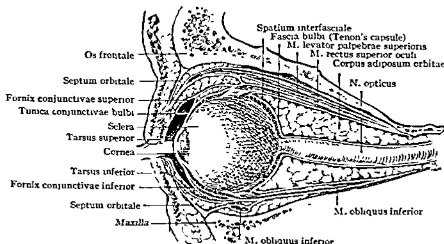


Fig. 53. DIAGRAMMATIC SAGITTAL SECTION THROUGH THE ORBIT TO SHOW THE FASCIA OF THE BULB (TENON'S CAPSULE).

to return to near its normal position a scleral resection, with or without insertion of a polyethylene tubing, may be performed to shorten the sclera. The amount of restitution of vision depends on the condition of the retina before detachment and upon the duration of the detachment.

TRANSPARENT OR REFRACTING MEDIA

In addition to the cornea, the media which focus the rays entering the pupil are the aqueous and vitreous humors and the muscle-controlled lens suspended between them.

ANTERIOR OR AQUEOUS CHAMBER AND THE AQUEOUS HUMOR. The space between the cornea and lens, the anterior compartment of the eye, is filled with transparent aqueous humor (Figs. 39, 47, 49). The iris diaphragm subdivides this space into anterior and posterior cameras: that between the iris and cornea, the anterior; that between the iris and lens with its suspensory ligament, the posterior. With the iris in actual contact with the lens, the posterior camera is only an angular interval, triangular in cross section, between the iris, ciliary processes, suspensory ligament of the lens, and the lens periphery. The chambers communicate by the pupillary orifice.

The mode of formation of the aqueous humor and its manner of filtration are exceedingly important in relation to ocular tension (p. 50). This transparent fluid is secreted into the aqueous space by blood vessels of the ciliary processes. The collection of excess aqueous fluid is absorbed into the *iris angle spaces* (of Fontana) in the pectinate ligament, and from there filters into the circular venous sinus of the sclera (*canal of Schlemm*) (p. 50). Through the canal of Schlemm and the ciliary veins anastomosing with it, the aqueous humor leaves the eye. The required or physiologic tension in the globe probably is maintained by regulation of secretion and absorption of the fluid.

Obstruction to the filtration space about this angle renders escape of fluid difficult and brings about the grave accidents consequent upon increased intraocular tension. When the pupil is dilated, the periphery of the iris tends to encroach on the iris angle and render fluid passage difficult. Giving a pupil-dilating drug, such as atropine, in conditions of increased tension may precipitate glaucoma.

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course it gives off the *central artery of the retina* and, later, the two posterior long and several short *ciliary arteries* near the entrance of the nerve into the sclera.

The ORBITAL VEINS gradually converge as they pass backward into the orbit where they form the *superior* and *inferior ophthalmic trunks*, which usually unite before leaving the orbit by way of the superior orbital fissure to empty into the cavernous sinus (Figs. 12, 13, 17). The anastomoses which the superior orbital vein forms with the supraorbital and angular veins of the face are of great practical importance, because through them infections of the face, especially about the upper lip and nose, are carried readily to the orbit, cavernous sinus and brain.

The ORBITAL NERVES include the optic nerve, the motor nerves to the eye muscles and the sensory nerves to the orbital contents. The *oculomotor nerve* innervates all the muscles of the eyeball except the superior oblique and the lateral rectus, which are supplied by the trochlear and abducens nerves, respectively.

The optic nerve (Fig. 49), or nerve of sight, consists mainly of the axons or central processes of the cells in the ganglionic layer of the retina. Within the bulb of the eye, these axons lie in the layer of nerve fibers of the retina. They converge toward the optic papilla, or disk; gathered there into small bundles, they pierce the choroid and sclerotic coats to become the optic nerve (Fig. 51). The nerve, as it courses posteriorly toward the brain, traverses the central region of the orbit, passes through the optic foramen, and then, approaching the nerve of the other side, joins it to form the optic chiasm. From the chiasm the fibers are continued in the optic tracts, which diverge from each other to reach the base of the brain near the cerebral peduncle. The optic nerve corresponds to a tract of fibers within the brain rather than to the other cranial nerves, because of its embryological development and its structure. It is developed from a diverticulum of the lateral aspect of the forebrain. The constituent fibers probably are third in the chain of neurons from the visual receptors to the brain. The nerve is invested by three sheaths which are prolonged from the corresponding meninges of the brain (Fig. 55).

The optic chiasm rests upon the tuberculum sellae of the sphenoid bone and on the diaphragma sellae of the dura, where it may become deformed by a meningioma (Fig. 56).

The *ciliary ganglion* has a sensory supply from the nasociliary branch of the ophthalmic nerve, a motor supply from the inferior division of the oculomotor nerve, and sympathetic fibers from the cavernous plexus on the internal carotid artery. The *short ciliary nerves* leave the ganglion to supply the coats of the eyeball, the iris and the ciliary muscles. It is possible to inject an anesthetic into the region

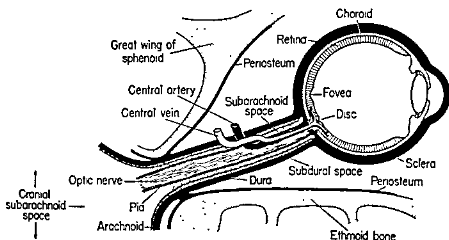


Fig. 55. CONTINUITY BETWEEN THE LAYERS OF THE EYEBALL AND THE SHEATHS OF THE OPTIC NERVE, AND BETWEEN THE LATTER SHEATHS AND THE CRANIAL MENINGES.

The sclera, or fibrous tunic, encloses the posterior five sixths of the bulb of the eye (the anterior portion being the transparent cornea); it forms an external sheath for the optic nerve and is continuous with the cranial dura mater. A prolongation of the pia mater immediately invests the nerve. Between the two lie spaces which are continuous with those of subdural and subarachnoid positions within the cranial cavity. (From Gifford's Textbook of Ophthalmology, revised by Adler, 1957.)

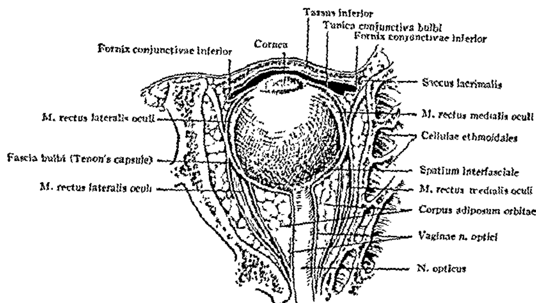


Fig. 54. DIAGRAMMATIC CROSS SECTION THROUGH THE ORBIT TO SHOW TENON'S CAPSULE.

retraction of the muscles after tenotomy or after section in enucleation of the eyeball. That part of the fascia below the bulb is slung like a hammock from side to side of the orbit as a *suspensory ligament;* its extremities are fixed to the lacrimal and zygomatic bones. In resection of the maxilla the attachments of the suspensory ligament should be maintained to keep the eyeball in position.

The intimate relation between Tenon's capsule and the ocular muscles must be borne in mind in muscle operations to correct *strabismus* (squint). Even when an ocular muscle tendon is severed at the scleral attachment, it still exerts an action on the globe through its attachment to Tenon's capsule and its capsular prolongation.

RETROBULBAR OR RETRO-OCULAR SPACE

The retrobulbar space lies behind the fascia of the bulb and contains the eye muscles, which, with the exception of the inferior oblique, take their origin from the orbital bone and the periosteum near the optic foramen. It also contains the ocular vessels and nerves lying close together in the semifluid fat and the connective tissue which abounds here (Figs. 53, 54).

ACTION OF THE EYE MUSCLES. The eye is *adducted* by the action of the internal rectus muscle, assisted toward the end of its course by the superior and inferior recti. It is *abducted* by the external rectus muscle, reinforced toward the end of the course by the two oblique muscles, and *elevated* by the superior rectus and inferior oblique (Figs. 53, 54). The superior rectus muscle carries the eye upward and a little medially. The inferior rectus muscle acting alone *depresses* the globe and carries it a little inward; the superior oblique muscle acting alone carries it downward and a little outward; their combined action carries the globe straight downward. The main purpose of the neuromuscular mechanism of the eye is to secure binocular fixation, and actions of the eyes therefore are correlated so that there are no interfering movements.

The *levator palpebrae muscle* inserts mainly into the tarsal plate of the upper lid. This muscle raises the lid, thereby widening the palpebral fissure, and acts in apposition to the orbicularis oculi muscle, which closes it.

The four *recti muscles* attach to the sclera behind the cornea and are fused to the fascia of the bulb, which they pierce. Advancement and resection of the muscles, or retroplacement, are practiced commonly to cure strabismus, section of the scleral and fascial attachments being complete or incomplete according to the degree of muscle action required.

VESSELS AND NERVES OF THE ORBIT. The OPHTHALMIC ARTERY, a branch of the internal carotid, supplies all the contents of the orbit. The terminal ophthalmic branches, the *supraorbital, frontal* and *nasociliary arteries,* supply the palpebral and nasal regions of the face. The ophthalmic artery emerges from the cranial cavity through the optic foramen. Early in its

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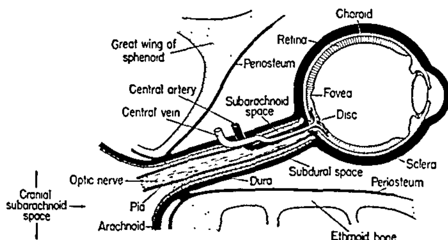


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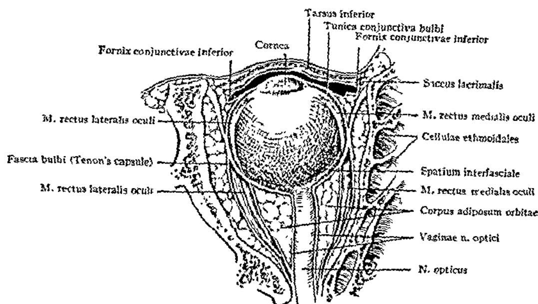


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the iris, and the accommodation is impaired as a result of ciliary paralysis. There is a slight exophthalmos from the paralysis of all but one of the recti muscles. *Partial paralysis* of this nerve is more common than complete paralysis. *Paralysis of the fourth* or *trochlear nerve* is an uncommon type of isolated muscle palsy and frequently is congenital. Paralysis of a single muscle, if acquired, usually affects the external rectus, innervated by the *abducens nerve*, and is evidenced by internal strabismus and an inability to turn the eyeball outward.

Paralysis or *section of the cervical sympathetic chain* results in a narrowing of the palpebral fissure because of the drooping of the upper lid, following paralysis of the superior palpebral muscles (of Müller). There also is a contraction of the pupil from paralysis of the dilating radial muscle fibers of the iris, and a slight retraction of the globe, enophthalmos. This symptom complex, called *Horner's syndrome*, may be caused by tumors in the neck, goiter or enlarged lymphatic glands, as well as by trauma, surgical or otherwise.

ORBITAL TUMORS AND FOREIGN BODIES. Orbital tumors may originate in the contiguous cavities and invade the orbit secondarily. The outstanding symptom is protrusion of the eye, or exophthalmos. Foreign bodies have been embedded in the orbit over a period of years without causing trouble.

PULSATING EXOPHTHALMOS. Protrusion of the eyeball, pulsation in the globe and surrounding parts, a bruit heard over the regions about the eye, and marked distention of the vessels of the conjunctiva and lids constitute the clinical picture of pulsating exophthalmos. Its cause usually is an arteriovenous aneurysm resulting from rupture of the internal carotid artery into the cavernous sinus, the arterial blood being forced under pressure into the veins of the globe and associated structures. Rupture of the carotid artery usually is the result of trauma, particularly fracture of the base of the skull. Spontaneous ruptures caused by degeneration of the vessel wall may occur. Compression of the carotid artery on the same side as the exophthalmos diminishes the pulsation and the bruit, and ligation may result in a cure of the exophthalmos.

DEFORMATION OF CHIASM. The chief symptoms of suprasellar meningiomas are produced by compression of the optic nerve, optic chiasm or optic tract; the degree of change in visual acuity and in visual field is dependent upon the position and size of the tumor (Fig. 56). The tumors are described as tough and slow-growing and having a mulberry-like appearance externally. Asymmetrical growth is usual. As a consequence, one optic nerve is involved more than the other, with corresponding asymmetry in defects in the visual fields. As the tumor enlarges, neighboring structures are affected; new signs and symptoms then appear, such as dyspituitarism and internal hydrocephalus from closure of the foramen of Monro with resulting papilledema.

ANEURYSMS OF CIRCLE OF WILLIS. Intracranial aneurysms may simulate tumors symptomatically by direct pressure upon surrounding structures or through blood lost in extravasation from a ruptured vessel.

Aneurysms of the carotid part of the arterial circle are more common than those in the vertebral part (Fig. 57). To the ophthalmologist, aneurysm of the anterior cerebral artery is of particular interest because, simulating a tumor, it presses upon the optic chiasm.

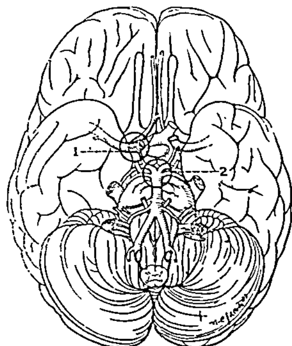


Fig. 57. COMMON SITES OF ANEURYSMS OF VESSELS WHICH FORM THE ARTERIAL CIRCLE OF WILLIS; SCHEMATIC.

Key: 1, Carotid portion of the so-called circle, in which aneurysms are far more common than in the vertebral division of the system; 2, middle cerebral arteries, which are affected more frequently than any other pair. (From Gifford's Textbook of Ophthalmology, revised by Adler, 1957.)

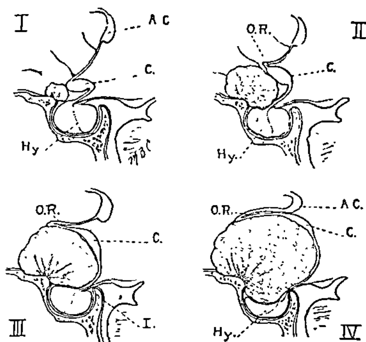


Fig. 56. FOUR STAGES IN DEFORMATION OF THE OPTIC CHIASM PRODUCED BY MENINGIOMAS OF THE TUBERCULUM SELLAE.

I, Initial stage. *II*, Stage (autopsy) probably presymptomatic. *III*, Early stage of syndrome, still surgically favorable. *IV*, Tumor, 20-gm., unfavorable for surgery.

Abbreviations: *A.C.*, anterior commissure; *C.*, chiasma; *Hy.*, hypophysis; *I.*, infundibulum; *O.R.*, optic recess. (From Cushing and Eisenhardt: Meningioma, Thomas, Springfield.)

of the ciliary ganglion and thereby obtain complete regional anesthesia during operations on the ocular globe.

Surgical Considerations

RETROBULBAR ABSCESS. Retrobulbar infection develops and spreads rapidly in the abundant fat of the orbital compartment. It may complicate disease of the nasal accessory sinuses, particularly ethmoiditis, follow orbital periostitis or operative infection of the orbit, or be a sequel to facial erysipelas. The abscess sometimes occupies almost the entire orbit, pushing the globe forward and greatly embarrassing its movements and circulation. Thrombosis in the ophthalmic veins, following an abscess in the orbit or secondary to some neighboring suppurative focus, may lead to cavernous sinus thrombosis, which is frequently fatal, although modern treatment with anticoagulants and antibiotics may produce a cure.

STRABISMUS, OR SQUINT. Squint is a manifest deviation of one of the visual axes. It may be a result of deficiency in the fusion sense in the brain (concomitant squint) or be caused by paralysis of one or more of the ocular muscles (paralytic squint). In normal binocular vision the image is projected on corresponding points of both retinas, and a single image results. Injury or paralysis of one of the eye muscles disturbs the delicate balance necessary for normality, and the images fall on dissimilar points of the retina, resulting in double vision, or *diplopia*. In concomitant squint, diplopia does not ensue, owing to the voluntary suppression of one image. In paralytic squint the eye deviates to the side of the stronger muscle pull, with a resulting squint, or strabismus. If the eye is turned laterally, the squint is *divergent* (external strabismus); if mesially, *convergent* (internal strabismus). All the recti muscles, save the external, are supplied by the oculomotor nerve, paralysis of which leads to lateral deviation, or divergent squint. Paralysis of the sixth nerve, the abducens, which supplies the lateral rectus muscle, causes internal strabismus, a condition sometimes seen in skull injuries and brain tumors.

NERVE PARALYSIS. *Complete paralysis* of the oculomotor nerve presents a complex picture. There is a drooping of the upper lid (ptosis), and the almost immobile eye has a divergent squint caused by the unopposed action of the lateral rectus muscle. The pupil is dilated because of the paralysis of the circular fibers of

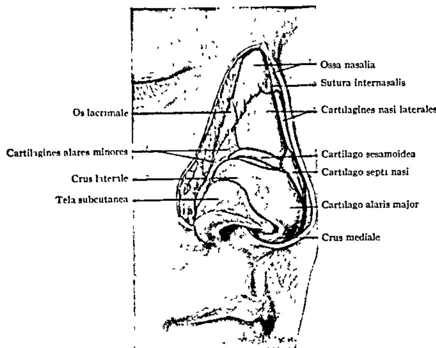


Fig. 59. SKELETAL STRUCTURES OF THE EXTERNAL NOSE.

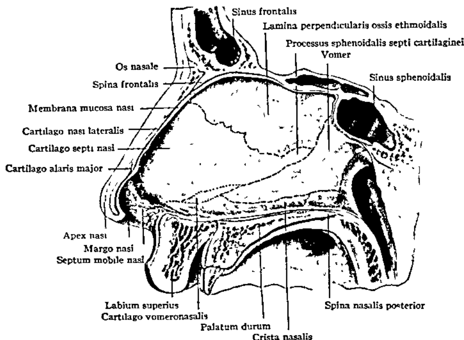


Fig. 60. PARAMEDIAN SAGITTAL SECTION THOUGH THE LEFT NASAL FOSSA TO SHOW THE NASAL SEPTUM. The component elements of the septum are mapped out by dotted lines.

directed against the base of the nose may break the cribriform plate of the ethmoid or the anterior wall of the frontal sinuses. Fracture of the cribriform plate of the ethmoid is a compound fracture of a portion of the root of the skull. The dura is exposed to injury and infection from the nasal fossae. If there is associated fracture of the nasal bones with epistaxis, it is difficult to know whether or not cerebrospinal fluid has escaped.

Ulcerating syphilis in the cartilaginous septum causes the bridge of the nose to be-

Olfactory Apparatus

The olfactory apparatus may be divided topographically into the external nose, nasal fossae and paranasal sinuses.

EXTERNAL NOSE

The external nose is pyramidal in shape (Fig. 58). Its open posterior wall is applied directly to and communicates with the nasal fossae. The free anterior margin or bridge runs to its root at the forehead and terminates below at the apex or lobule of the nose. The lateral walls of the pyramid expand into the mobile alae (wings) of the nose. The base presents two apertures or nares separated by a median column or septum. Because of the cosmetic importance of the nose and the high incidence of deformity from disease and injury, many devices have been developed to improve its appearance or repair its loss.

SUPERFICIAL STRUCTURES. The skin is thin and movable over the root of the nose, but is thick and adherent over the apex, where inflammation is exceedingly painful because of the tenseness of the parts and the consequent pressure on the nerves. The skin of the nose is a favorite site for tuberculosis (lupus) and for rodent (carcinomatous) ulcer. About the apex, comedos, or blackheads, and subcutaneous cysts are common. When acne rosacea becomes exaggerated to the degree that an increase in the connective tissue takes place, the base and sides of the nose are converted into a lobulated mass. This condition is known as *rhinophyma.*

SKELETAL STRUCTURES. The lateral, greater and lesser alar cartilages, the cartilage of the septum, and the nasal bones make up the skeletal framework of the external nose (Figs. 59, 60). At their upper extremities, at the root of the nose, the nasal bones articulate with the frontal bone, the perpendicular plate of the ethmoid bone and with the frontal processes of the maxillae; they are narrow, thick and well protected from injury. At their lower extremities they are broad and thin, much exposed to trauma, and frequently are fractured. Nasal bone fracture almost always is compound because of the rupture of the closely adherent mucous membrane, and therefore is accompanied by epistaxis. Fractured nasal bones heal readily because of their great vascularity.

The lacrimal bones form part of the mesial wall of the orbit and articulate with the frontal processes of the maxillae (Fig. 36), for which they act as shock absorbers, so that a blow on the nose, with or without nasal fracture, may cause fracture of the lacrimal bones. A blow

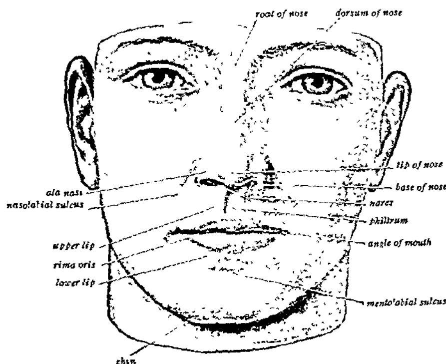


Fig. 58. MOUTH, CHIN AND EXTERNAL NOSE.
(Sobotta and McMurrich.)

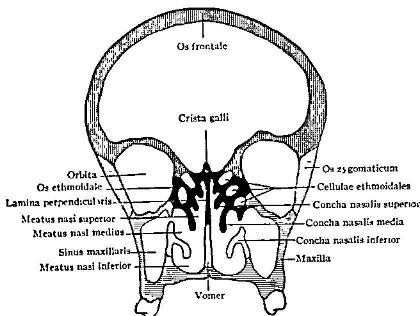


Fig. 62. FRONTAL SECTION THROUGH THE SKULL, ORBITS, NASAL FOSSAE AND PARANASAL SINUSES TO SHOW THE BONES WHICH FORM THE NASAL FOSSAE AND PARANASAL SINUSES.

Variations in shading denote the individual bones. (After Corning.)

treme antero-inferior part of the septum is membranous and flexible. In most adults the septum presents a considerable amount of deviation, usually most marked at the union of the ethmoid and vomer, or along the union of the vomer and the septal cartilage; however, it may occur in any part of the septum and ranges from a small bulge to a sharp ridge or spur. The deviation may be sufficient to block one nostril, with obstruction of the openings of the paranasal sinuses, leading to congestive reaction and inflammation in their cavities.

LATERAL WALL OF THE NASAL FOSSA; THE CONCHAE (TURBINATES). The lateral walls of the nasal fossae are modeled characteristically by three turbinate scrolls or nasal conchae, placed one above the other (Figs. 62 to 64). The scrolls project as more or less horizontally disposed ledges from the lateral walls and have their free margins directed downward and inward. The bony framework of the superior and middle conchae is furnished by the ethmoid bone, but that of the inferior or maxillary concha is an independent bone. The spaces which the ledges overlie and partially shut off from the nasal cavity are the superior, middle and inferior meatuses.

The *superior concha* is much the smallest, and its anterior extremity usually lies beneath the middle of the cribriform plate. The depression above and behind the superior concha is the spheno-ethmoidal recess; it communicates with the sphenoid sinus.

The *middle concha* extends forward much farther than the superior and reaches the level of the anterior extremity of the cribriform plate. Its free margin descends almost vertically and then extends backward and downward to the posterior aperture of the fossa. On the outer wall of the nasal fossa, just anterior to the middle turbinate, is a moundlike elevation known as the agger nasi.

The *inferior concha*, lying along the lower part of the lateral wall of the nasal cavity, is on the functional respiratory pathway of the nose. It reaches to within 2 cm. of the middle of the anterior naris, and its posterior tip lies 1 cm. in front of the pharyngeal orifice of the auditory (eustachian) tube. This last relation is responsible for the symptoms of middle ear disease consequent upon hypertrophy of the posterior extremity of the inferior turbinate. Swelling of the inferior turbinate usually indicates sinus disease, mainly that of the antrum, since pus from the antrum runs over it; at times, at its posterior extremity is a large polypoid mass almost filling the choana.

NASAL MEATUSES. The *superior meatus* presents, anteriorly, the openings of most of the posterior ethmoid cells; in the spheno-

come depressed and to present a characteristic saddle-like appearance.

ANTERIOR NARES, OR NOSTRILS. Each nostril opens directly into the vestibule, the slightly expanded forward portion of the nasal cavity. The vestibule is lined with skin, and in its lower half are hairs and sebaceous glands, frequent seats of annoying and distressing infection. Since the floor of the nose is on a lower level than the plane of the nasal fossae, the apex should be elevated with the nasal speculum in examination of the nasal cavities.

VESSELS AND NERVES. The external nose has an abundant vascular supply and, for this reason, responds to the many plastic operations performed upon it. The lateral and angular terminations of the external maxillary artery form the main arterial supply. The veins empty into the anterior facial vein and establish a communication through the ophthalmic vein with the cavernous sinus (Fig. 17). Even slight infections about the nose and upper lip must be considered potential of serious extension to the cerebral meninges. An abscess should be allowed to localize under hot compresses and should not be opened by untimely incision. The lymphatics drain to the submaxillary and deep cervical lymph nodes, and their network over the nose communicates with that over the inner part of the vestibule and the nasal mucous membrane.

NASAL FOSSAE

The anterior portion of the external nose, the vestibule, expands above and behind into triangular spaces or fossae which are separated from each other by the septum, which lies between the base of the skull and the hard palate (Figs. 61 to 63). The fossae communicate more or less freely with the nasal accessory or paranasal air sinuses in the bodies of the frontal, sphenoid, ethmoid and maxillary bones. They open on the face by the vestibule and the anterior nares, and into the pharynx by the posterior nares or choanae.

Each fossa has a mesial, lateral, superior and inferior wall, consisting essentially of a bony and cartilaginous framework covered by mucous membrane. The maxillae and ethmoid bones form the bulk of the bony skeleton and furnish the cavities of the larger accessory sinuses. The mucous membrane is attached closely to the periosteum and cartilage, so that any inflammation of its surface is propagated to the underlying structure. The horizontal portion of the maxilla (palatine process) forms the floor of the fossa, and the mesial portion forms part of the lateral wall. The mesial surface of the ethmoid bone forms the upper half of the lateral wall, the cribriform plate, the roof of the fossa, and the perpendicular plate, the upper half of the bony septum. The vomer is the bony framework of the septum in its lower portion.

MESIAL WALL OF THE NASAL FOSSA, THE SEPTUM. The mesial wall of each fossa is a midsagittal partition, the nasal septum, formed by the perpendicular plate of the ethmoid (Fig. 60), the vomer and the septal cartilages, and covered by mucous membrane. The ex-

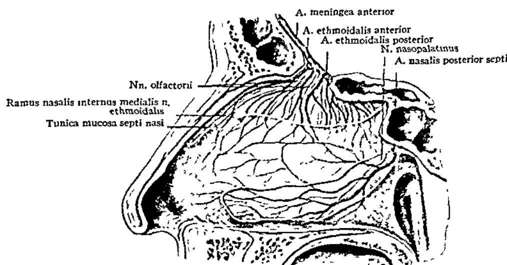


Fig. 61. ARTERY AND NERVE SUPPLY OF THE SEPTUM.

ethmoidal recess is the entrance into the sphenoid sinus (Fig. 64).

The *middle meatus* presents the orifices of the frontal and maxillary sinuses and of the anterior and middle ethmoid cells. The middle ethmoid cells project into the meatus, forming a rounded elevation, the *ethmoidal bulla* (Fig. 64). This conspicuous, bleblike, cell-containing structure is revealed by turning the middle nasal concha upward. Hypertrophy of the ethmoid bulla may be sufficient to obstruct the nasal fossa. The middle turbinate overlying the meatus yields before the expanding cells and may press against the septum, sometimes to the degree of obstructing the nasal fossa on the opposite side. Below the bulla is a sharp crescentic lamella, the *uncinate process*. Between the free border of this process and the ethmoid bulla is the cleftlike *semilunar hiatus*, which leads from the middle meatus into a groove of variable depth and dimensions, the *ethmoidal infundibulum*.

Generally, the ethmoidal infundibulum ends blindly as one or more anterior infundibular ethmoid cells. Posteriorly, it ends in a pocket or merges gradually with the middle meatus. Occasionally, it is continuous anatomically with the *nasofrontal duct*, the infundibulum of the frontal sinus, or, where the nasofrontal duct is absent, with the frontal sinus proper. In the depth of the ethmoidal infundibulum are the aperture of the frontal sinus and the openings of the infundibular group of the anterior ethmoid cells.

The *orifice of the maxillary sinus* ordinarily is posterior to that of the frontal sinus, which frequently lies in such a position that discharge from the frontal and ethmoidal cells crosses indirectly through the infundibulum into the ostium of the maxillary sinus. The opening of the maxillary sinus into the middle meatus may be single, or there may be a number of accessory orifices (Fig. 64, *B*). The middle turbinate bone, when congested, may block drainage of the whole region. Attempt to rectify this obstruction formerly constituted indiscriminate removal of the turbinate; at present a submucous resection of the nasal septum is performed. This allows the turbinate to swell without preventing adequate sinus drainage. If the turbinate is cystic, polypoid or otherwise diseased, the affected part is trimmed away.

Between the attached border of the uncinate process and the inferior nasal concha, the lateral wall of the middle meatus is wholly membranous. It may present the *accessory maxillary ostium*, a direct communication between the middle meatus and the maxillary sinus. The *suprabullar furrow* or recess, located between the ethmoidal bulla and the attached border of the middle turbinate, contains the ostia of most of the bullar group of anterior ethmoid cells, usually classed as middle ethmoid cells.

The *frontal recess* is the frontal portion of the middle meatus and is a pouchlike extension with which the frontal sinus communicates by way of the nasofrontal duct (Fig. 64, *A*). Usually the ethmoidal infundibulum and the nasofrontal duct are separate channels, but occasionally they are united.

The *inferior meatus*, bounded by the concave surface of the inferior turbinate and the lateral wall of the fossa, is funnel-shaped and varies in size with the degree of projection of the turbinate from the wall. The nasal ostium of the nasolacrimal duct is concealed in the forward portion of the meatus. Resection of a part of the turbinate may be required to expose properly the meatus and the opening of the *nasolacrimal duct*.

Superior Wall or Roof of the Fossa. The roof of each nasal fossa is but 3 to 4 mm. wide and is coextensive with the cribriform plate of the ethmoid. Considering the roof as cranially arched, the cribriform plate forms the horizontal or middle portion; the body of the ethmoid with the wing of the vomer and the sphenoid process of the palate bone forms the curved posterior portion; and the frontal and nasal bones form the curved anterior portion. The roof is an anteroposterior groove with its concavity inferior because of the approximation of the lateral and mesial walls of the fossa. It extends to the nasopharynx, with no line of demarcation.The region may be divided into anterior or nasal, superior or frontal-ethmoidal, and posterior or sphenoid portions.

The thin but compact cribriform plate supports the olfactory lobe of the brain and separates the nasal from the cranial cavity. The plate is fragile because it is pierced by numerous orifices for the passage of the fibers of the olfactory nerve and their meningeal investments. In the angle between the sphenoid and ethmoid bones is the *spheno-ethmoidal recess*, which receives the opening of the sphenoid sinus. After resection of the superior turbinate

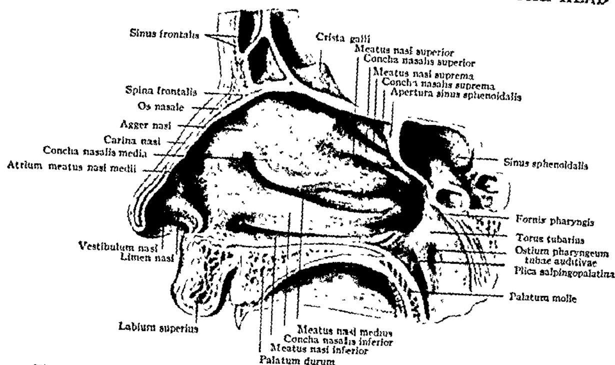


Fig. 63. CONCHAE (TURBINATE BONES) ON THE LATERAL WALL OF THE RIGHT NASAL FOSSA.

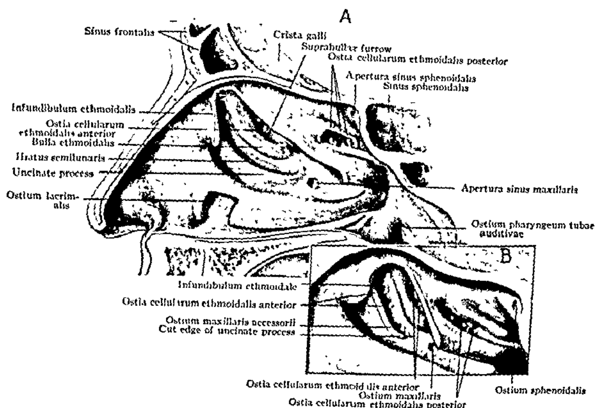


Fig. 64. LATERAL WALL OF THE RIGHT NASAL FOSSA WITH PARTS OF THE TURBINATES REMOVED TO SHOW DIAGRAMMATICALLY THE OPENINGS INTO THE PARANASAL SINUSES.

In *A*, portions of the superior, middle and inferior turbinates have been removed; the openings into the frontal and ethmoid sinuses are strictly diagrammatic, since they are too small to locate accurately.

In *B*, the anterior portion of the middle turbinate is removed to show the sinus openings in the semilunar hiatus of the middle meatus; part of the uncinate process has been cut away.

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bone a probe, with its tip dipped a little downward and passed backward along the roof of the spheno-ethmoidal recess, will enter the sphenoid sinus.

A *meningocele*, projecting through the roof of the nasal fossa into the nasal cavity, has been mistaken for a nasal polyp and removed with fatal outcome from meningeal complications. Fracture of the cribriform plate is exceedingly serious, since the meninges are exposed to the infected areas of the nasal fossae. The abundant epistaxis accompanying cribriform plate fracture may mask a considerable flow of spinal fluid through the nose. *Meningitis* sometimes complicates infection of the nasal fossae. The inflammation extends through the cribriform plate, which, through the perineural and perivascular sheaths, brings the venous drainage of the nose into continuity with the meninges.

Inferior Wall or Floor of the Nasal Fossa. The floor of the nasal fossa is much wider than the roof. The mucous membrane is supported by the palatal processes of the maxillary bones and the horizontal plates of the palate bones. While almost horizontal, it presents a gentle slope backward. Along this floor a probe can be passed into the nasal portion of the pharynx and into the auditory (eustachian) tube. A nasal tube can be passed with ease along this pathway.

Posterior Openings of the Nasal Fossae, the Choanae. By the method of nasal examination known as *posterior rhinoscopy*, the posterior orifices of the nasal fossae may be seen. Their osseous boundaries keep them permanently open for the ingress and egress of air. They are limited above by the body of the sphenoid bone and the alae of the vomer, below by the line of junction of the hard and soft palates, and laterally by the medial plates of the pterygoid processes of the sphenoid bone.

In posterior rhinoscopy a mirror is introduced through the mouth behind the soft palate and is illuminated through the mouth. In favorable circumstances there may be seen on each side the nasal opening, middle meatus, auditory tube, mucous membrane of the upper nasopharynx, the septum and part of the inferior meatus. These structures also can be made out with the examining finger thrust behind and above the soft palate. Each adult posterior aperture (choana) is an oval orifice about 2.5 cm. in vertical diameter and 1 cm. in transverse diameter. The size of the openings must be appreciated when fitting plugs for them in the attempt to arrest severe hemorrhage from the nose. Hypertrophy of the posterior extremity of the turbinates, pharyngeal adenoid growths, polyps and tumors obstruct the posterior nares, and may be as efficient obstacles to nasal breathing as any intranasal obstruction.

Nasal Mucous Membrane. The nasal cavities are lined by mucous membrane continuous with that of the pharynx (Figs. 63, 65), paranasal sinuses and lacrimal sac; this continuity is important because of the interrelationship of the diseases of these areas. The mucosa may be divided into respiratory and olfactory areas, since it not only lines the tracts followed by the respired air, but also covers the cells which receive the impressions for smell. The *respiratory mucosal tract* occupies the lower two thirds of the region, is covered with ciliated epithelium, and is supplied richly with glands capable of producing a copious secretion, sometimes so free as to be mistaken for a flow of cerebrospinal fluid. The thickness of the mucosa varies greatly, reaching several millimeters over the inferior turbinate; it is hardly a millimeter thick on the lateral wall. The mucosa is bound down closely to the underlying bone so as to constitute a mucoperiosteum. On both lower turbinate bones the vessels form a sort of erectile tissue, developed in cavernous spaces, which plays an important role in the physiology and pathology of the nasal cavity. In chronic catarrhal inflammation these cavernous spaces are distended with blood until the nasal cavity is occluded and breathing is obstructed. The mucous membrane over the turbinates, when it is the seat of chronic inflammation, may undergo polypoid degeneration. The *olfactory mucosal region* is limited in extent and is highly specialized. It embraces an area situated above the center of the middle turbinate bone and the corresponding part of the septum.

Vessels and Nerves. The principal *arterial* supply of the nasal fossae comes from the ophthalmic arteries through the anterior and posterior ethmoid branches, and from the internal maxillary artery through the sphenopalatine arteries (Fig. 61). The *veins* accompany the arteries and form a rich network beneath the mucous membrane of the middle and inferior turbinate bones. The ethmoidal veins open into the superior sagittal sinus, and the nasal veins into the ophthalmic veins and thence

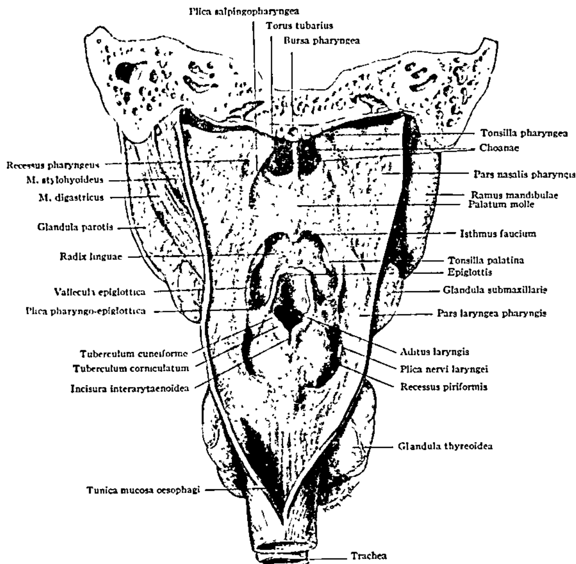


Fig. 65. POSTERIOR VIEW OF THE PHARYNX AND ESOPHAGUS.
The posterior wall of the pharynx is opened.

into the cavernous sinuses. These venous communications between the intracranial and intranasal circulations explain the danger to the meninges and the brain of infective processes in the nose. The *lymph drainage* from the cavities of the nose is by way of the deep cervical lymph nodes along the internal jugular vein.

The fibers of the *olfactory nerves* pierce the openings of the cribriform plate of the ethmoid to supply the mucous membrane of the superior third or olfactory part of the nasal fossae.

The *sensory nerves* for the respiratory tract of the nasal fossae come from the ophthalmic nerve through the ethmoidal branch and from the maxillary nerve through the branches of the sphenopalatine ganglion.

Surgical Considerations

COMPLICATIONS OF INFLAMMATION OF NASAL MUCOUS MEMBRANE. The pivotal position which the nasal chambers occupy with reference to the paranasal sinuses, the tear apparatus, conjunctiva, pharynx and auditory (eustachian) tubes explains the importance of the mucous membrane which lines these cavities in common. Inflammation of the lining membranes extends up the auditory tubes by way of the posterior nares and the pharynx. Aching of the face and frontal headache may

occur from involvement of the maxillary and *frontal sinuses. Serious intraorbital* or intracranial disease may follow ethmoid or sphenoid sinus involvement. Meningitis may arise when *infection extends through the cribriform* foramina along the neural and vascular sheaths. The severer forms of rhinitis and complicating *pharyngitis may involve the retropharyngeal* lymph nodes and cause retropharyngeal abscess and even, although rarely, involve the deep *cervical lymph nodes.*

The mucous membrane, in spite of an abundant blood supply, has no submucous *areolar tissue between it and the underlying* periosteum and perichondrium, and is slow to heal. Mucous membrane involvement is caused by mechanical or bacterial irritation. The accompanying congestion causes swelling of the nasal and allied mucous membranes, producing closure of the orifices communicating with the paranasal sinuses. Closure results in retention of inflammatory products. The subsequent infection and thrombosis destroy the sinus lining. Reaction to inflammation results in the forma*tion of granulation tissue, and reparative proc*esses result in polypoid degeneration or scar formation.

NOSEBLEED (EPISTAXIS). The general vascularity of the nose, and the presence of a rich venous plexus deep to the turbinate mucous membrane, together with exposure to trauma, explain the great frequency of nosebleeding. When the bleeding point is in the anterior portion of the septum, as it most frequently is, it is arrested easily by plugging the anterior nares. When the bleeding point *is posterior* and cannot be found, or when a sinus is the source of hemorrhage, bleeding must be *checked by plugging both the anterior and pos*terior nares. To plug the posterior nares, a ligature is threaded through the nose to the pharynx and out through the mouth. To the middle of the ligature is attached a plug of gauze the size of a walnut. *This plug is drawn* by the upper end of the ligature into the posterior nares. The two ends of the ligature are tied *together so that* the plug can be pulled against the posterior nares, or withdrawn and reapplied if necessary. One or both nasal fossae then are plugged from before backward.

SEPTUM DEVIATIONS. The septum usually is deviated. *The deviation most commonly occurs* at the junction of the bony with the cartilaginous portion. The dorsum or free border of the septum almost always is in the median plane. Although the septum may be essentially straight, yet a marked ridge or spur occurs on one or the other side and produces asymmetry.

Trauma, which often is unrecognized, and disturbances in development are the commonest and most important etiologic factors in *septum deviation. Septal* deviation does not mean that the breathing space of the narrowed nasal fossa is encroached upon seriously, but *frequently the septum is forced against the* jutting middle or inferior turbinate, setting up irritation and inflammation. This inflamma*tion and its resultant congestion may obstruct* the orifices of the paranasal sinuses and bring about sinus disease; this is the anatomic reason *for septum resection in sinus and turbinate* disease. Septal spurs are found on the anterior edge of the vomer, and sometimes form a distinct ridge of bone running upward and backward. Infection of the septum is exceedingly dangerous, since the septal veins may carry the infection through the cribriform plate of the ethmoid to the meninges.

METHODS OF EXAMINATION. *Since the anterior nares* are directed downward and are on a lower plane than the floor of the nose, an *anterior rhinoscopic examination* of the nasal cavities can be made best with the head thrown slightly backward and the nose lifted up (Fig. 66). The dilating speculum introduced into the anterior nares should not be inserted beyond the cartilaginous portion of the nose because of the pain produced by pressure against the unyielding bony structure. The anterior part of the middle concha, *a considerable portion of* the inferior concha, a small portion of the middle meatus, and part of the inferior meatus may be seen under favorable conditions. The

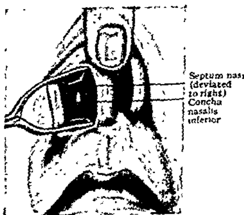


Fig. 66. ANTERIOR RHINOSCOPIC EXAMINATION.

opening of the nasolacrimal duct cannot be seen, although it is but 2.5 cm. from the nostril and 2 cm. from the nasal floor, since it lies concealed beneath the depressed anterior extremity of the inferior concha.

Posterior (pharyngeal) rhinoscopic examination is done with difficulty because of the sensitiveness of the pharynx, but with some practice it can be managed readily. While the patient breathes through the nose, the tongue is depressed by the examiner and a small mirror, similar to that of a laryngoscope, is carried through the mouth into the pharynx behind the soft palate. With light reflected through the mouth, the posterior nares, the posterior extremity of the nasal septum, the conchae and the corresponding meatuses, especially the middle conchae and middle meatuses, may be seen. The roof of the nasopharynx and the pharyngeal orifices of the auditory tubes usually can be made out. With a finger introduced through the mouth, the same structures can be differentiated, and such outgrowths as pharyngeal adenoids, tumors and abscesses can be felt.

PARANASAL SINUSES

In recent years knowledge of the sinuses related to the nasal fossae has assumed an increasingly important role to clinicians and surgeons, since sinus disease is much more common than was formerly supposed; attempts to deal with it have developed a special field in surgery. The air-containing, irregularly shaped diverticula of the nasal fossae are included in the "upper respiratory tract." Their communications with the nasal fossae are more or less narrow orifices which may be occluded by the congestion arising from swelling of their lining mucous membrane.

In the third or fourth month of fetal life the sinuses form as outpocketings or evaginations of areas of the mucous membrane of the nasal meatuses. The sphenoid sinus arises as a constriction of the posterosuperior region of the nasal fossa. The points of outgrowth are the ostia or orifices of communication between the sinuses and the nasal fossae. These mucous membrane sacs expand into the bones related to the nasal walls, with absorption of the bone, pneumatizing large portions of the frontal, ethmoid and maxillary bones and forming frontal, ethmoidal and maxillary sinuses (Fig. 67).

There is no constancy in the anatomy of the paranasal sinuses, and great variations in elaboration, size and type are common. A conventional type of sinus should not be visualized. Under normal conditions there is an interchange of air in the paranasal sinuses during respiration, and good ventilation in them is essential to health. Although the nasal cavities exert an important influence over vocalization, the paranasal sinuses apparently do not.

Frontal Sinuses. The frontal sinuses, formed bilaterally at the expense of the frontal bones, are the most anteriorly placed of the nasal accessory sinuses and may be considered extensions of the anterior ethmoid cells (Fig. 67). Each may develop as a direct extension of the whole frontal recess of the middle meatus from one or more anterior ethmoid cells which originate in the frontal recess, or, occasionally, from the anterior extremity of the ethmoid infundibulum. At the age of six years they are but a bud of mucous membrane in the vicinity of the anterior extremity of the semilunar hiatus; at the age of eight years the frontal sinuses insinuate their way between the two plates of the frontal bones, and develop to their maximum size by about the twenty-fifth year.

The anterior wall of each sinus forms the prominence of the forehead above the eyebrow. Its upper wall separates the sinus from the frontal lobe of the brain, a relation which explains the endocranial and orbital complications of severe frontal sinus disease. The nasal part of the inferior wall is in relation with the ethmoid cells and the roof of the nasal fossa.

Occasionally cells extend beyond the confines of the frontal bone into the sphenoid, nasal and parietal bones and, by way of the crista galli, into the ethmoid bone. Supernumerary sinuses are common, and each has its own connection with the nasal fossa. One sinus may develop at the expense of the other and cause the septum between them to be displaced from the median line. Subdivision or pocketing by more or less complete septa makes irregular what otherwise would be a smooth cavity. The sinus most commonly opens into the middle meatus by the frontonasal duct, or infundibulum of the frontal sinus. This duct is about 2 cm. long, runs downward and slightly backward from the posterior wall of the sinus, and opens at or near the anterior end or frontal recess of the semilunar hiatus. It is usual for

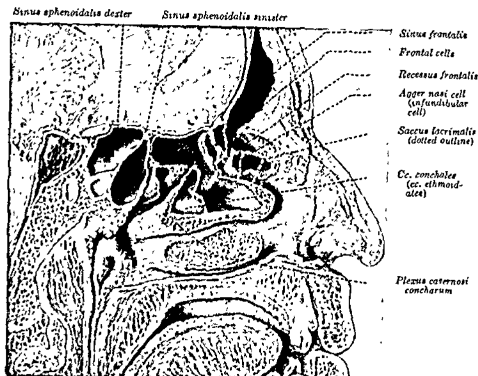


Fig. 67. LATERAL NASAL WALL WITH THE PARANASAL SINUSES EXPOSED (THE MAXILLARY SINUS EXCEPTED).

Note the extension of the posterior ethmoid cells into the middle nasal concha, forming conchal cells; an agger nasi cell (infundibular anterior ethmoid cell) overlies the lacrimal sac; in the endonasal approach to the lacrimal sac and to the nasolacrimal duct, ethmoidal cells of this type would be opened before the sac is reached. (After Schaeffer: The Nose, Olfactory Organ, and Accessory Sinuses.)

one or more of the anterior ethmoid cells to open with the frontonasal duct into the semilunar hiatus. A frontonasal duct directly continuous with the ethmoid infundibulum is not unusual.

In about 50 per cent of cases the relation between the nasal end of the frontonasal duct and the frontal end of the ethmoid infundibulum is so intimate that some of the secretion *from the frontal sinus drains readily toward* and into the ethmoid infundibulum. The opening of the maxillary sinus into the middle meatus may be placed so that it receives the pus from the frontal sinus and anterior ethmoid cells as the pus gravitates along the groove of the semilunar hiatus. The maxillary antrum thus may be converted into a cesspool, giving symptoms which divert attention from the true focus, which is frontal and anterior ethmoid sinus disease.

Maxillary Sinuses. The maxillary sinuses (antra of Highmore) are paired cavities occupying the interior of the maxillary bones and conforming, in the main, to their shape (Fig. 68). Extensive pneumatization of the alveolar, palatal, frontal and zygomatic processes of the maxilla affords the sinuses an increased volume. The volume may be augmented by a marked encroachment of the mesial wall on the cavity of the nasal fossa. The capacity of the sinus is diminished by thickening of the sinus walls, retention of teeth, diminished pneumatization of the body and outlying processes of the maxilla, and by a deep anterior cranial fossa.

By the oval or elongated *maxillary ostium*, the sinus communicates with the deep aspect of the posterior half of the ethmoid infundibulum (Fig. 64, *B*). The ostium may vary from a minute opening to a complete replacement of the floor of the infundibulum. The slitlike space between the free border of the uncinate process and the ethmoidal bulla is the semilunar hiatus, which connects the middle meatus with the ethmoid infundibulum. The maxillary opening is placed disadvantageously as a drainage aperture, because it is located at the upper part of the sinus and drains into the narrow, deep and much restricted ethmoid infundibulum. In about one third of adults there is an *accessory maxillary ostium* which communicates directly between the middle meatus and the maxillary sinus. The opening

lies behind the ethmoid infundibulum or projects into it between the posterior third of the uncinate process and the related part of the inferior turbinate. The accessory ostium is placed more advantageously for drainage purposes than is the maxillary ostium, because it is lower and frequently is larger.

The fossa of the maxillary sinus is of a quadrangular pyramidal shape, its base lying mesially and its apex extending laterally toward the zygomatic (malar) bone. The nasal or mesial wall is divided for practical purposes into an upper and lower part, the junction line being along the attachment of the inferior concha (Fig. 68). The upper part is in relation with the middle meatus, and the lower with the inferior meatus, where it extends below the level of the palate.

The orbital or superior wall presents a longitudinal bulge which runs backward and contains the infraorbital nerve. To this nerve relationship is attributed the infraorbital face pain accompanying maxillary sinus involvement. The anterior wall extends from the alveolar border to the margin of the orbit. Most maxillary sinuses have their floor below the floor of the nasal fossa and markedly below the lowest usual point of surgical entrance, the inferior meatus. At times half of the vertical extent of the sinus is posterior to the point of perforation. It is obvious that pus cannot be removed by dependent drainage with an opening above the palatal level. Pus in copious quantity in the maxillary sinus empties with the head turned so that the affected cavity is uppermost; the sphenoid empties most easily with the head bent forward; and the frontal, with the head thrown backward.

The roots of the upper three molar and two bicuspid teeth ordinarily make a bulge into the floor of the sinus, and are separated from the cavity by a thin layer of spongy bone. Not infrequently this spongy tissue is deficient, and the uncovered roots project into the sinus, a matter of great surgical importance, since it explains the production of maxillary sinusitis by dental caries and the establishment of drainage for empyema of the antrum by accidental or intentional removal of one of these teeth. The floor of the sinus is not smooth or regular, and often presents incomplete septa, forming divisions into which inflammatory products tend to seep; these may be inaccessible to treatment by antrum puncture. These divisions may be of such size as to require individual attention and should be considered in cases resistant to ordinary treatment.

Ethmoid Labyrinth. The ethmoid cells

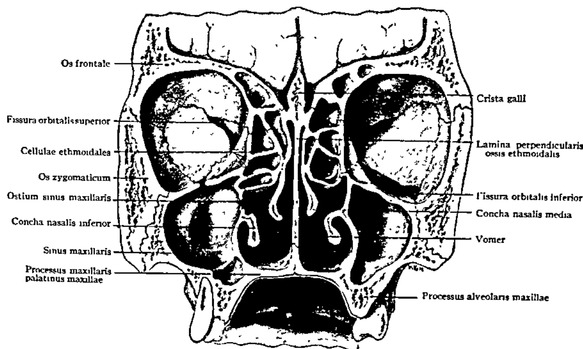


Fig. 68. Frontal section through the brain, orbits, paranasal sinuses and nasal fossae to show their interrelations.

eight to ten in number, are cavities with paper-thin walls, lying in the thickness of the lateral masses of the ethmoid bone between the upper parts of the nasal fossae and the orbits, between the frontal and sphenoid sinuses, and between the floor of the cranial cavity and the middle turbinate (Figs. 62, 67, 68). The cells as a whole constitute the ethmoid labyrinth, which occupies the entire ethmoidal field; hence the individual cells are many if small, and few if large. The cells open into the superior and middle meatuses of the nasal fossae, and their mucosa is continuous with the nasal mucosa. An ethmoid cell usually extends into the middle meatus and forms the ethmoid bulla.

An anterior and posterior group of ethmoid cells may be differentiated. The *anterior* or *middle meatus cells* generally are about five in number and open into the semilunar hiatus. They may be divided into frontal anterior cells, opening into the ethmoidal infundibulum, and bullar anterior cells, opening into the middle meatus below, above or upon the ethmoid bulla. In the last arrangement the bulla is made pneumatocystic by the cells. The frontal sinus may be considered an anterior ethmoid cell, opening as it does on the infundibular portion of the semilunar hiatus. The posterior cells lie in the posterior portion of the lateral mass of the ethmoid. Their orifices open above the attached border of the concha and communicate with the superior and middle meatuses.

The relations of the ethmoid air cells to the cranial cavity are more extensive than those of the frontal and sphenoid sinuses. The bone separating these cells from the cranial meninges is compact, save at the level of the shallow olfactory grooves, where the cells bulge upward lateral to the crista galli. The bony wall here may be paper-thin and sometimes is lacking. This relation explains the meningeal and cerebral extensions, meningitis, cerebral abscess, subdural abscess and sinus thrombosis which may complicate ethmoiditis.

SPHENOID SINUSES. The sphenoid sinuses are two paramedian cavities of irregular cube shape which lie within the body of the sphenoid bone (Figs. 64, 67) and not infrequently extend into the great wing, pterygoid process, and rostrum of the sphenoid, and into the basilar process of the occipital bone. The sinuses are separated by a thin and often much deviated septum. They commonly replace certain posterior ethmoid cells and, occasionally, come far enough forward to establish communication with the maxillary sinus. The reverse may occur, and one or more posterior ethmoid cells grow posteriorly into the body of the sphenoid bone, restricting its contained sinuses.

Extremely rudimentary or large sinuses may be encountered; their capacity varies from 0.5 to 30 cc. They are largest toward the age of twenty to twenty-five years. A sinus may be only a small cavity behind the sphenoid orifice in the anterior part of the body of the sphenoid bone, or a large, irregular cavity encroaching extensively upon the opposite sinus.

Since the symptoms of sphenoid sinusitis are vague and overshadowed by the symptoms of other sinus involvement, the prognosis as to operative results should be guarded.

Surgical Considerations

FRONTAL SINUS DISEASE AND DRAINAGE. Congestion of the mucous membrane lining the frontal sinuses, frequent in acute coryza, produces a dull ache over the glabella and superciliary arches. When drainage from the sinus is blocked, purulent fluid collects, producing an *empyema*. With the frontal duct open, pus is conveyed along the semilunar hiatus to the opening of the maxillary sinus, infecting the maxillary cavity. Since the anterior ethmoid cells open with the frontal duct into the infundibulum of the semilunar hiatus, these cells may be involved easily in frontal sinus disease. Infection of the frontal bone may result from frontal sinus suppuration by the development of an osteitis. Such an infection may terminate in abscess of the frontal lobe and in meningitis.

The aim of all *intranasal surgery* for frontal sinus disease is improved drainage. Removing obstructions within the nose, clearing the frontonasal opening, resection of the anterior end of the middle turbinate, and curettement of the anterior ethmoid cells are followed so frequently by relief of frontal suppuration that they should always be performed before resorting to frontal sinus operation. When operation is indicated, the usual resection of the middle turbinate is followed by removal of the nasal wall above the anterior end of the resected bone, thus eliminating the anterior ethmoid

cells. A sound now passes readily into the frontal sinus, so that its passage can be enlarged and cleared.

Originally, frontal empyema was treated by *extranasal operation.* A trephine or chisel opening was made in the bone of the front wall of the sinus. Since an anterior opening could not drain the sinus in its most dependent portion, and the drainage of the irregularly shaped and loculated cavity was difficult at best, this simple method often failed. Both curative and cosmetic results are attained by the Killian operation, which involves the removal of the anterior and inferior walls of the sinus, frontal process of the maxilla, upper portion of the lacrimal bone, and adjacent ethmoid cells, with preservation of a rim of bone at the supraorbital margin for cosmetic reasons. Curettement of the mucous lining of the sinuses completes the operation.

The *combined intranasal* and *extranasal approach* effects an efficient and permanent drainage. Curved incisions are made over the mesial portion of each eyebrow, avoiding, if possible, the supraorbital nerve. The bone is removed, the cavities are explored, and granulations and pus cleared away. Intranasally, the bone surrounding the nasal opening of the frontonasal duct is removed.

Maxillary Sinus Disease and Drainage. Infection of the maxillary antrum may occur from carious fangs of teeth present in its cavity; also from infection of adjacent frontal, sphenoid and ethmoid air cells. Since the frontal and anterior ethmoid cells open into the infundibulum, seepage along the infundibular groove is directed into the maxillary antrum. If the maxillary orifice is not occluded, pus from the sinus may overflow and escape into the middle meatus; drainage is facilitated by placing the affected sinus uppermost. Pus flowing from beneath the middle turbinate is an important diagnostic sign.

The sinus can be approached surgically through the lateral wall of the inferior meatus, through a dental alveolus or through the canine fossa (Figs. 69, 70). For years the dental alveolar approach was used for empyema of the antrum and was commended for its simplicity and the quick relief it occasioned. Unfortunately, reinfection from the mouth was common, and the tendency for the trocar opening to close was great. Should a diseased tooth project into the antrum, it now is deemed best to remove the tooth, and curet the socket without establishing communication with the sinus and to develop, instead, a naso-antral window for drainage. To prevent sacrifice of a healthy tooth, the sinus can be drained through the mouth by everting the upper lip and drilling or trephining the canine fossa just above the second bicuspid tooth. If bone here is thin, the antrum is reached conveniently. As extensive an opening as desired may be made, but the roots of the teeth should not be exposed.

For permanent communication the removal of a section of the lateral wall of the nasal fossa is of great value. This may be accomplished with or without removal of the inferior concha. An extensive resection is advisable to attain free drainage and to compensate for the tendency of the opening to close over. Resection, extended to include a portion of the lateral wall of the inferior meatus and necessitating partial resection of the inferior concha, should remove as little of the inferior concha as is consistent with adequate drainage.

Examination of the maxillary sinus is made with the patient in a dark room and with an electric light placed in the mouth. The outlines of each maxillary antrum, if empty, are clearly made out. If a sinus is inflamed, that side of the face will appear darker, the shadow being produced by accumulated pus or mucous membrane thickening. This examination gives valuable information as to the size of the sinus and the presence or absence of disease. Pathologic changes can be demonstrated with absolute certainty only when the sinus is opened, although the roentgenogram affords valuable information.

Benign or malignant tumors may originate in the antrum. The tumor invades the nose by rupturing the thin mesial wall, the orbit by pushing up the roof of the cavity, the mouth by eroding the floor of the sinus, and the cheek by eroding the thin anterior maxillary wall. The dense malar bones do not yield to invasion, and there is little tendency for the growth to spread backward. As the infraorbital nerve runs along the roof of the sinus, and the nerves to the upper teeth run in its walls, they may be pressed upon by growths, producing neuralgia of the face and teeth.

Ethmoid Disease and Drainage. The cells of the ethmoid labyrinth usually are involved when the other paranasal sinuses are infected seriously. Conversely, their infection will cause

suppuration in the other sinuses, as evidenced by the fact that suppuration in the adjacent sinuses often ceases when ethmoid cells are drained properly. Repeated attacks of infection lead to changes in the ethmoid mucosa, which contribute to the ultimate formation of polypoid tissue. Once polyps are formed, the mucosa shows a tendency to hyperplasia in adjoining cells. The more chronic the process, the greater the amount of polypoid infiltration. When ethmoid cells are subject to a chronic suppurative process, there is no hope of their being restored, since they are so small that nothing short of exenteration effects a cure. There seems to be a definite relation between sinus disease and the common bronchial affec-

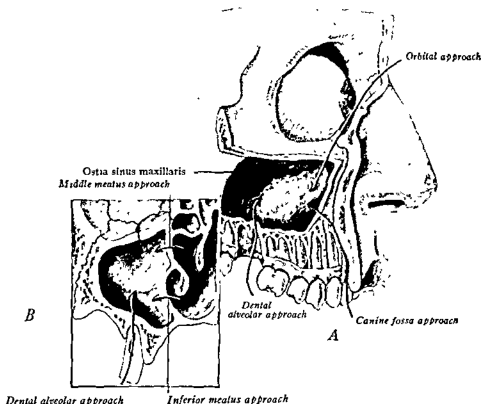


Fig. 69. SURGICAL APPROACHES TO THE MAXILLARY SINUSES.
A is a diagrammatic lateral view; *B*, a frontal section.

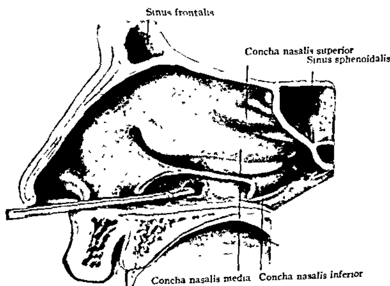


Fig. 70. APPROACH TO THE MAXILLARY SINUS THROUGH THE INFERIOR MEATUS.
A part of the inferior concha need or need not be removed.

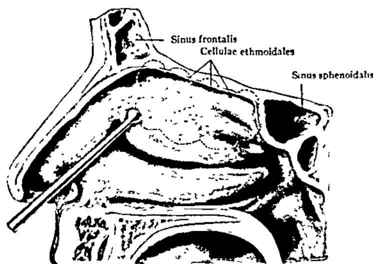


Fig. 71. DIAGRAMMATIC PROJECTION OF THE ETHMOID CELLS ON THE LATERAL WALL OF THE NASAL FOSSA.
The curet indicates the ethmoid area to be removed first.

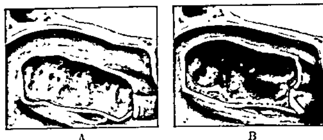


Fig. 72. OPERATIVE STEPS IN INTRANASAL EXENTERATION OF THE ETHMOID CELLS.
The lateral and most superior cells cannot be removed safely through this approach.

tions such as asthma, chronic bronchitis, and bronchiectasis. These complications are an additional indication for sinus surgery.

Operation on the ethmoid cells involves the removal of the diseased cells and some of the adjacent normal tissue. According to the extent of involvement of the ethmoid cells, a greater or less amount of the middle turbinate bone is resected. The anteriorly placed cells are the most accessible (Fig. 71). Safety lies in keeping below the roof of the nose and following the cells backward to the outer walls, appreciating that the lateral boundary of the cells is the mesial orbital wall (Fig. 72). The ethmoid bulla is opened, and polypi, if present, are removed.

ROUTES TO THE SPHENOID SINUS; TRANSSPHENOID APPROACH TO THE HYPOPHYSIS. Operation on an infected sphenoid sinus, by whatever route, entails as complete a removal of the anterior wall of the sinus as possible, in the ethmoid as well as in the nasal portion. Removal of this wall is necessary because of the tendency to prolonged discharge of pus. The region deserves a wholesome respect because of the close association of the cavernous sinuses with their enclosed internal carotid arteries, and the optic nerves. The sphenoid is exposed readily in any of the extranasal operations on the frontal sinus. After the removal of the ethmoid labyrinth the next procedure is the removal of the anterior wall of the sphenoid sinus.

An exposure of the hypophysis is effected by removing the front wall and roof of the sphenoid. The mucous membrane is elevated from both sides of the septum as in submucous resection, and a portion of the bone and cartilage is removed, including the inferior end of the perpendicular plate of the ethmoid, together with most of the vomer. The turbinates on each side are flattened against the lateral nasal

walls. The anterior wall and bony roof of both the sphenoids are removed, exposing the hypophysis.

Auditory Apparatus

The auditory apparatus should be considered with full appreciation of the significance of its connection through the auditory tube with the mucous membrane of the nasopharyngeal tract. The continuity of mucous membrane throughout the correlated mechanisms of this tract makes possible the extension of a localized infection or irritation and congestion of the upper air tract to the lungs through the trachea, to the mucous membrane of the head in general, and to the ear through the auditory tube. For this reason, aural conditions are dependent, to a great extent, upon the condition of the mucous membrane of the upper air passages. An exact knowledge of the accessory spaces associated with the tympanic cavity is as important in the interpretation of auricular pathologic change as is that of the accessory sinuses in pathologic change of the nasal passages.

The hearing apparatus is comprised of a central and a peripheral portion. The central portion, lying within the cranial cavity, is made up of the central pathways of the eighth nerve and the cortical area in the superior temporal gyrus. The peripheral portion is located, for the most part, within the temporal bone.

The peripheral hearing apparatus embraces the external, the middle and the internal ear.

The external ear includes the auricle, which projects from the side of the head, and the external acoustic (auditory) meatus, leading inward from the deepest part of the auricle to the tympanic membrane (Figs. 73 to 75).

The middle ear, or tympanum, is a small air chamber in the temporal bone. It is lined with mucous membrane and contains an articulating chain of three ossicles—malleus, incus and stapes—together with their minute muscles and ligaments. Laterally, the malleus is attached to the tympanic membrane; medially, the base (footplate) of the stapes fits into the vestibular (oval) window in the outer wall of the internal ear. The tympanic cavity proper communicates in front with the nasal portion of the pharynx by means of the auditory tube; above, with the epitympanic recess; behind, with the tympanic antrum and, through the latter, with the mastoid air cells (Figs. 73, 75).

The internal ear is composed of a series of delicately membranous chambers and connecting passages, enclosed within corresponding, but more capacious, cavities hollowed out of the petrous portion of the temporal bone. The component parts of the membranous (otic) labyrinth are the following: the cochlear duct (scala media); the saccule, utricle and the endolymphatic sac, and the small ducts—utricular, saccular and endolymphatic ducts

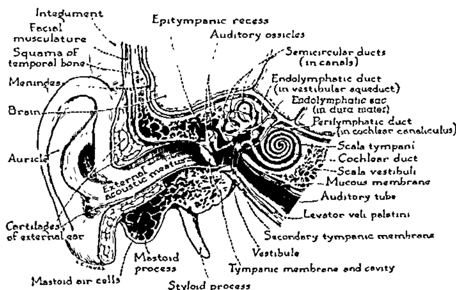


Fig. 73. GENERAL RELATIONSHIPS OF PARTS OF THE INTERNAL AND MIDDLE EAR AND THE EXTERNAL AUDITORY MEATUS.

(From Anson and Bast: Monograph in preparation.)

and the ductus reuniens—which bring these three chambers into communication (Fig. 92, *a*). The cochlear duct occupies the cochlea of the so-called bony (periotic) labyrinth (Fig. 91, *a*). The utricle and saccule are both contained within the vestibule; the endolymphatic duct is lodged within the vestibular aqueduct, while a portion of its terminal sac, projecting into the cranial cavity, is covered by the dura mater of the brain; the semicircular ducts occupy osseous canals of generally similar form. The membranous labyrinth contains a fluid called endolymph. The membranous chambers and ducts do not completely fill the bony labyrinth; the resulting space is occupied by a fluid termed perilymph.

The external ear may be studied with reference to its main structures, the auricle or pinna, and the external auditory (acoustic) canal. For convenience of description, the middle ear is divided into its more or less clinical divisions: tympanic membrane, tympanic cavity, mastoid antrum, mastoid air cells and auditory tube. Each of these regions, besides being correlated, has a physiology, pathology and field of surgery of its own.

EXTERNAL EAR

Auricle or Pinna. The auricle is attached to the side of the head behind the temporomandibular joint and in front of the mastoid process, on a line from the eye to the external occipital protuberance. The lateral surface looks slightly forward and is irregularly concave. The largest and deepest of its concavities is the funnel-like fossa which surrounds the opening of the external auditory meatus (Fig. 74).

Fibrocartilages, ligaments, rudimentary musculature and a skin-covering compose the auricle. The fibrocartilages are thin, flexible structures which are the supporting framework for all the pinna save the lobule, and permit free movement of the body of the ear. Extrinsic ligaments attach the auricle to the temporal bone, while intrinsic ligaments maintain the cartilages in position. There are both extrinsic and intrinsic muscles which have little action. The skin is more closely adherent to the anterior than to the posterior surface of the auricle, and in an inflammatory disease, such as erysipelas, the skin over the ear may become extremely swollen and exquisitely tender from perichondrial inflammation.

A fairly rich *arterial supply* for the auricle (pinna) arises from the external carotid artery by way of the superficial temporal artery in front and the posterior auricular artery behind.

The *venous drainage* enters the superficial temporal vein in front and the external jugular vein below. From the mesial aspect of the ear and the posterior aspect of the auditory meatus the *lymphatic vessels* collect into the mastoid glands at the mastoid tip. They seldom drain into the retroauricular glands, which commonly are involved in scalp infections. The swelling of enlarged retroauricular glands from

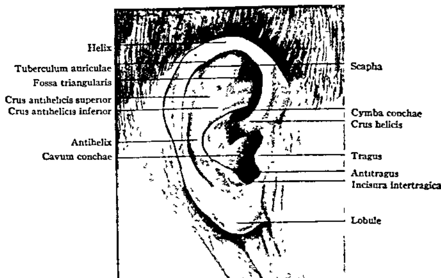


Fig. 74. EXTERNAL EAR.

infection of some small scalp area has frequently been confused with the edema of mastoid disease. The efferent lymphatic trunks pierce the sternocleidomastoid muscle near its origin and enter the deep cervical chain. The lymphatics of the external aspect of the pinna drain to the anterior or preauricular glands, and to some extent to the glands about the parotid, and eventually drain into the deep cervical chain. The pinna frequently is frostbitten because its vessels lie superficially in scant subcutaneous tissue.

External Auditory Meatus or Canal. An external fibrocartilaginous and an internal bony portion make up the canal, which runs about 3.5 cm., from the concha to the tympanic membrane (Fig. 73). The outer third of the wall of this canal is fibrocartilage, and the inner two thirds is bone. The *fibrous portion* of the fibrocartilaginous part of the canal is concave and makes up the superior and posterior walls. The *cartilaginous portion* is formed from the tonguelike cartilage which makes up the auricle and is split by two horizontal breaks or incisurae to give mobility to the auricle. Through these incisurae an abscess in the parotid may discharge into the external meatus, or a deep-lying furuncle of the meatus may open and discharge into the parotid.

The *bony portion* is derived from the temporal bone. The upper wall is formed from the squamous portion, and the upper part of the posterior wall from the petrous portion as it expands to form the mastoid process. Cholesteatomas of the antrum often break through this wall into the external meatus. A periostitis along this segment of the meatus may complicate mastoiditis. In the newborn the osseous portion is absent. It is not formed until the temporal bone is developed fully. Because of the mesial obliquity of the drum, which may be seen in frontal section, the inferior wall of the canal is longer than the superior wall. In a general way, the tube is flattened anteroposteriorly and undergoes a sort of torsion from without inward until gradually its anterior wall becomes antero-inferior. The result is that the ellipse representing the section of the tube, while vertical in its external portion, has its greater diameter in the more mesial portion rather inclined toward the horizontal.

The direction of the canal in the cartilaginous portion is upward, inward and forward; that in the bony portion is inward, downward and forward. Thus there is a convex curve near the middle of the canal. To facilitate examination of the canal, the pinna should be drawn upward and backward, which places the cartilaginous and bony portions of the tube in line and eliminates the curve.

A conspicuous landmark, the *suprameatal spine*, lies at the upper, posterior part of the margin of the bony meatus (p. 95). To it attaches the superior ligament of the auricle.

The skin adheres closely to the wall it covers, and is continuous with the skin over the concha and over the external wall of the tympanic membrane, to which it furnishes the external layer.

The *anterior wall* of the canal is in such intimate relation with the temporomandibular joint that the condyle of the mandible pushes into the membranous and cartilaginous portion sufficiently to produce a constriction. The constriction disappears when the jaws are opened. Areolar tissue separates a prolongation of the parotid gland from the anterior wall of the canal. A fall or blow upon the chin may break the wall, and the ensuing hemorrhage may be interpreted as bleeding from cranial fracture. The *posterior wall* is a bony partition separating the canal from the mastoid air cavities, with which it has a fairly intimate relationship. The canal is tender and swollen, and even is invaded by pus in certain types of mastoid disease. When a radical mastoid operation is performed in serious middle ear disease, the entire posterior wall of the external meatus is removed. In relation with the middle cranial fossa is the *superior wall*, formed from the squamous portion of the temporal bone. This wall may be permeated with air cells in communication with the cavities of the middle ear. These cells are susceptible to purulent disease of the middle ear, and their presence explains the path by which pus from an otitis media may invade the external canal without perforating the drum membrane. Bone disease in the wall may lead to cranial meningitis. Through the intermedium of the parotid fascia, the *inferior wall* is in relation with the contents of the parotid compartment. Defects in the cartilage, loosely filled with connective tissue, afford a path of infection from a parotid abscess to the external canal. The drum membrane closing the inner extremity of the canal is of such surgical importance that it is described separately (see below).

Surgical Considerations

INFECTIONS AND EAR WAX DEPOSITS IN THE EXTERNAL AUDITORY MEATUS (CANAL). The sebaceous glands in the skin of the canal frequently are the foci for small abscesses which are exquisitely painful because of the indistensibility of the skin in the region. The skin of the meatus, when infected, may exude a mucopurulent discharge justifying the term *otitis externa*. The skin of the canal, as well as that of the auricle, suffers from varying types and degrees of eczema, the most severe of which penetrate to, but rarely through, the drum. Reciprocally, an otitis media discharging through the drum may inflame the skin of the canal, setting up an eczema. Excessive secretion of the ceruminous glands often plugs the meatus, causing temporary deafness. Forcible effort to remove wax frequently results in impaction and possible infection.

FOREIGN BODIES IN THE CANAL. Foreign bodies may remain for some time in the external auditory canal without causing serious damage or much inconvenience. They often are exceedingly difficult to extract, and more damage has been done by ill-advised attempts at removal with hairpins and matches than has been caused by their presence. Insects, small foreign bodies, or wax may be removed by syringing the canal gently with a stream of warm water. Instrumental removal should be attempted only with the instrument and foreign body well in view, and by one skilled in ear manipulation. Should the walls of the canal be swollen, the removal of the foreign body should be deferred until the swelling has subsided.

CHOLESTEATOMA EXTERNA. In this form of dermatitis, which occurs in the external auditory meatus, the epithelium desquamates rapidly, accumulates, and mixes with wax, sebum and other foreign material. The mass created irritates the underlying skin, which may become infected and even ulcerated. The condition is known as cholesteatoma externa. The process may progress to such an extent as to perforate the tympanic membrane or even cause necrosis and sequestration of part of the external canal. Healing after cholesteatoma may result in a narrowing or constriction of the canal.

ATRESIA OF THE EXTERNAL AUDITORY MEATUS. Atresia of the meatus may be acquired as the result of surgical or accidental trauma; it sometimes follows a prolonged external otitis, or it may be the result of a developmental anomaly. A severe conductive type of hearing loss accompanies an atresia. Surgical restoration of the patency of the meatus will restore normal hearing.

MIDDLE EAR

The middle ear, for purposes of topographic discussion, consists of the tympanic membrane, the tympanic cavity, the auditory tube and the mastoid air cells (Figs. 84 to 86).

TYMPANIC MEMBRANE

DEFINITION AND EXTERNAL CHARACTERISTICS. The tympanic membrane, or drumhead, is the thin, opaque, concave disk separating the external auditory canal from the tympanic cavity (Figs. 75, 77). It is resistant, and protects the tympanic cavity, of which it is part of the lateral wall. It also functions as a highly specialized part of the hearing mechanism, and vibrates with sound waves and transmits them along the ossicular chain to the labyrinth. It is fully developed at birth.

From external or otoscopic examination of this membrane valuable information may be derived as to conditions within the tympanic cavity. An exact knowledge of the main physical characteristics of the membrane and of the changes caused by disease is a valuable diagnostic and therapeutic adjunct.

In the development of acute middle ear disease, its thickness may be increased greatly by edema; this should be considered in paracentesis when a large opening is demanded. In chronic disease of the drum (myringitis) the membrane may be thickened irregularly and permanently. The color of the normal ear drum is a lustrous pearl gray, which is modified by the color of the light used and by the reflection from the inner wall and contents of the tympanic cavity. It undergoes great changes in color during ear disease, becoming reddened in otitis media and pale in sclerotic otitis. Its strength is the obstacle to the exit of pent-up pus in the tympanic cavity in acute middle ear disease. Paracentesis in this condition affords immediate, but sometimes only temporary, relief.

BONY INSERTION OF THE TYMPANIC MEMBRANE. The periphery of the membrane, save at the anterosuperior region, is inserted into the *tympanic sulcus* or groove in the tympanic

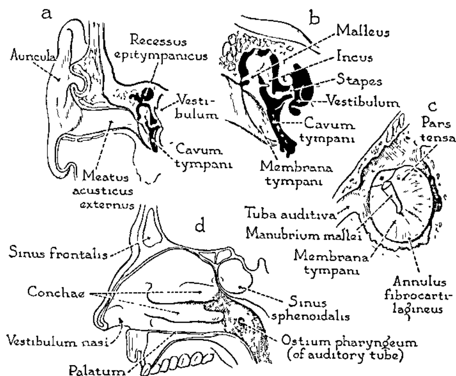


Fig. 75. EXTERNAL EAR (AURICLE AND MEATUS), MIDDLE EAR (TYMPANIC CAVITY WITH AUDITORY OSSICLES) AND AUDITORY TUBE.

a, External acoustic meatus, tympanic cavity and auditory ossicles. *b*, Tympanic cavity (middle ear) and vestibule (of internal ear). *c*, Lateral wall of the tympanum, showing the tympanic membrane and the manubrium of the malleus; flaccid part of the tympanic membrane is indicated by the asterisk. *d*, Pharyngeal orifice of the auditory tube.

part of the temporal bone, from which the strong fibrous portion of the membrane develops. The sulcus is absent for a distance of 5 mm. in the anterosuperior area, and the gap so formed is called the *tympanic incisura* (Rivini). Over this region the membrane has no strong fibrous constituent, but is represented simply by a thickened continuation of the covering of the auditory canal overlying the bulging mucosa which lines the tympanic cavity.

TOPOGRAPHIC DIVISION OF THE DRUM. From the surgical and structural points of view, the drum membrane is divided into two areas, one flaccid, and the other tense or vibrating (Figs. 76, 77).

A small part of the drumhead is occupied by *pars flaccida* (*Shrapnell's membrane*), which, in general, is in relation with the epitympanic recess and its contents, the ear ossicles. This portion of the membrane is within the area of the tympanic incisura, and its triangular outline is encompassed by the shorter anterior and the longer, more prominent posterior mucous folds or ligamentous bands which converge from the incisura to the button-like prominence of the lateral or short process of the malleus. The area demarcated is loose and flaccid, and lacks the fibrous-tissue framework of the remainder of the membrane. Its looseness allows it to bulge outward into the meatus as a pouch (of Prussak). Perforation here is common, since the pouch often harbors a chronic purulent collection of fluid from ossicle osteitis. During an acute attack of middle ear disease this pouch, along with involvement of the tense portion of the drum, may become distended with pus.

The larger *vibratory* or *tense portion* of the tympanic membrane is stretched tightly on a framework of fibrous and elastic tissue, to which the handle of the malleus is attached firmly. The tip of the hammer draws the membrane inward, forming a concavity, the apex of which is a depression known as the *umbo* (Fig. 76). The segment of membrane above the umbo is supplied freely with vessels and nerves, while that below it is less vascular and less sensitive.

EXTERNAL CONFIGURATION AND QUADRANT FORMATION. The attachment of the tip of the handle of the malleus is a little below and be-

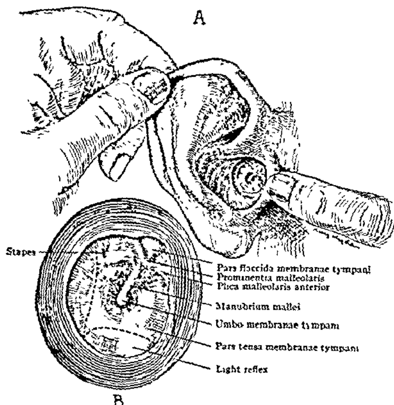


Fig. 76. LATERAL VIEW OF THE RIGHT TYMPANIC MEMBRANE. THE SIZE AND VISIBILITY OF THE MEMBRANE ARE MUCH EXAGGERATED.

B is a detailed drawing of the membrane; the dotted lines enclose areas though which paracentesis can be done safely.

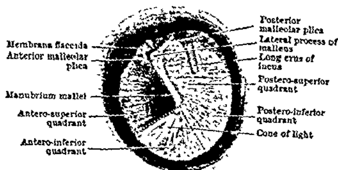


Fig. 77. NORMAL LEFT DRUMHEAD, SHOWING LIGHT TRIANGLE, MALLEUS HANDLE, AND FOLDS ABOUT THE SHORT PROCESS.

hind the center of the diaphragm. An essential and constant landmark, found when others are obliterated, is a small but distinct bulge, the *malleolar prominence*, lying in the anterosuperior region and pushed forward by the short process of the malleus. From this bulge a distinct line, the *anterior tympanic* or *malleolar fold*, runs forward to the periphery of the drum. Behind the malleolar prominence is a longer line, the *posterior malleolar fold*, which, with the anterior fold, the prominence, and the periphery of the drum, bounds the flaccid portion of the membrane. From the malleolar prominence a broad, grayish-white line is directed downward and backward as far as the umbo. This line or bulge corresponds to the *handle of the malleus*, which is included within the thickness of the membrane. A small, conspicuous, triangular, luminous region fans out in the antero-inferior portion of the membrane from its apex at the umbo to the periphery (Fig. 77). This is the cone of *light reflex*, a direct reflec-

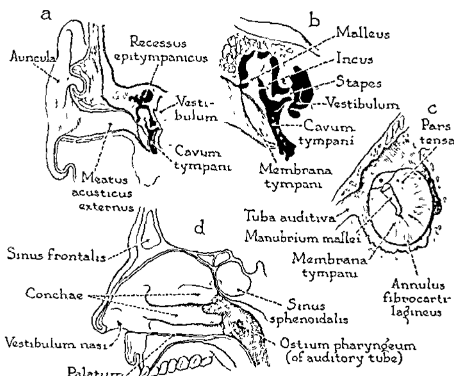


Fig. 75. EXTERNAL EAR (AURICLE AND MEATUS), MIDDLE EAR (TYMPANIC CAVITY WITH AUDITORY OSSICLES) AND AUDITORY TUBE.

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External Configuration and Quadrant Formation. The attachment of the tip of the handle of the malleus is a little below and be-

as influenza. The inflammation of the drumhead is accompanied by serous or hemorrhagic bullae and severe pain. As long as the middle ear is free from otitis media, the hearing is normal, serving to differentiate primary myringitis from the more common myringitis secondary to an acute otitis media. Inflammation of the drum is nearly always present in acute inflammation in the tympanic cavity (Figs. 78, 80). The ear drum may be swollen and congested, even ulcerated, without impairing the hearing seriously, unless the inflammation involves the entire tympanic cavity. As the largest vessels lie in the plexus which follows the malleus handle, redness is most frequent in that area. It is well to remember that the redness, as well as the luster, of an acutely inflamed drumhead may be obscured by exfoliating epithelium, and that marked swelling may obscure all landmarks. The inflammation generally subsides after the otitis media has cleared up. If the disease becomes chronic, deposits of chalk may occur within the membrane, thickening it, rendering it rigid, and interfering with its mobility, elasticity and vibrating function.

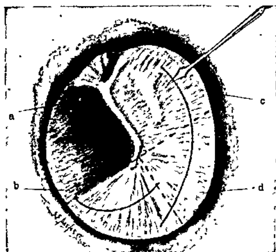


Fig. 79. INCISION (PARACENTESIS) OF THE LEFT TYMPANIC MEMBRANE.

The quadrants of the left tympanic membrane are shown: *a*, anterosuperior quadrant; *b*, antero-inferior; *c*, postero-superior; *d*, postero-inferior; the two most usual sites in which the ear drum is incised are shown. A paracentesis knife is making a long incision, parallel with, and a short distance in front of, the posterior border of the membrane, extending through one or more quadrants; a shorter, curved incision is seen in the antero-inferior quadrant. (From Bickham: Operative Surgery.)

INCISION OF THE EAR DRUM. Paracentesis, or simple puncture, of the drum should not be confused with incision of the drum (Fig. 79). It is agreed that simple puncture is not sufficient to secure adequate drainage, and that a free incision is attended by more immediate and more favorable results. No harm can come from free incision, since healing takes place quickly, sometimes before desired. If the drumhead is bulging, the incision should be made through the postero-inferior quadrant of the drumhead. This is usually the most prominent part of a bulging drumhead. The incision should always be made downward, carrying the knife away from the ossicles. Incision higher in the posterior quadrant may injure the ossicles and even luxate the stapes into the labyrinth, producing a suppurative labyrinthitis. Early incision in otitis media is accompanied by favorable results with relief from severe pain and shortening the course of the disease.

Incision of the tympanic membrane may also be indicated to evacuate the clear yellowish transudate that collects after prolonged eustachian tube occlusion.

Supra-umbilical incision may sever the attachment of the incus to the malleus, or may cut the chorda tympani nerve, causing a cessation of salivary secretion.

Early incision in otitis media is accompanied by favorable results, often shortening the course of the disease and preventing extension of the purulent infection into the mastoid cells.

RUPTURE OF THE MEMBRANE. The tympanic membrane may be ruptured by direct or indirect violence. The commonest forms of direct violence are scratching the drum with a sharp instrument, or attempts to remove a foreign body. Many ruptures result from sudden compression of the air in the external auditory canal which follows a fall or blow upon the ear. Rupture by indirect violence occurs commonly in skull fracture. The fracture may be transverse, running along the line of the external auditory canal through the labyrinth and across the tympanum. In this fracture there is discharge of blood and cerebrospinal fluid through the meatus. When the fracture line is sagittal, it follows the roof of the middle ear cavity and may not open the labyrinth. There then will be blood, but no cerebrospinal fluid, in the external meatus.

The membrane may burst outward after violent sneezing, coughing or vomiting, acts which transmit air under increased pressure

tion to the examiner's eye of those light rays falling upon that segment of the membrane perpendicular to the line of vision. The light reflex varies with differing degrees of concavity and obliquity of the drum.

Normally, the malleolar prominence, short process, handle of the malleus, and cone of light should be seen. In a particularly transparent drum there is occasionally seen a broad, grayish line which marks the long process of the incus, showing through the drumhead, approximately parallel with, and posterior to, the handle of the malleus. Farther back, the stapes, the tendon of the stapedius muscle and the niche of the round window sometimes are visible.

For topographic and surgical purposes the drum may be divided by two imaginary oblique lines. One is drawn downward and backward along the line of the handle of the malleus, the other at right angles to the first, downward and forward through the umbo, forming two supra-umbilical and two infra-umbilical quadrants (Fig. 77).

In the anterosuperior quadrant is the flaccid membrane (of Shrapnell), which forms the outer wall of Prussak's space and protects the ossicles in the tympanic cavity. It is the danger zone of the tympanum and must be avoided in paracentesis.

Surgical Considerations

Curvature Changes in the Membrane. While the normal curvature of the tympanic membrane depends largely upon the tension of the tensor tympani muscle, it may be depressed unduly as a consequence of unequal air pressure upon its surfaces. The depression may result from absorption of the air within the tympanum, closed by obstruction in the auditory tube, producing a partial vacuum (Fig. 78). Curvature changes are indicated by light reflex disturbance, the base of the cone, in some instances, narrowing to a line or disappearing. There may be an increase in prominence of the short process of the malleus and of the anterior and particularly the posterior tympanic folds. The handle of the malleus often is foreshortened and more horizontal than normal as it is drawn inward, backward and upward.

The tympanic membrane as a whole may bulge outward from fluid within the tympanum, or there may be a localized pointing of pus over any area of the membrane.

Otoscopic Examination. The meatus should be examined through an illuminated speculum for obstruction or occlusion resulting from acute inflammatory swelling (Figs. 78, 80). Pus, wax or foreign bodies may be present in the canal. The drum membrane should be examined carefully for luster, color, mobility, hyperemia, retraction, thickening or perforation. Attention should be directed along the handle of the malleus until the flaccid portion of the membrane is brought into view, and then to the anterior and posterior malleolar folds, after which the remainder of the circumference of the membrane should be inspected. Particular care must be exercised in examining the size, shape and position of the light reflex, or "luminous cone," and the degree of prominence of the short process of the malleus (Fig. 77). Alterations in the color, luster, apparent thickness, and curvature of the drum, as well as any abnormal areas on its surface, should be noted.

Inflammation of the Tympanic Membrane, Myringitis. Acute myringitis without otitis media is seen in certain viral diseases such



Fig. 78. CHANGES IN CURVATURE OF THE TYMPANIC MEMBRANE.

A, Indrawn membrane, caused by partial vacuum within the tympanic cavity. *B*, Bulging of the membrane produced by an acute otitis media. (From Dickie, in Jackson and Coates: The Nose, Throat, and Ear and Their Diseases.)

teriorly, with the tympanic cavity at a level somewhat above the entrance of the auditory tube. The attic is divided into mesial and lateral secondary cavities by the ossicles and the ligaments holding them to its walls. The mesial compartment communicates with the tympanic cavity proper, interrupted only by the tendon of the tensor muscle of the drum and its folds of mucous membrane. The lateral space is compressed between the flaccid portion of the drum membrane laterally, and the head of the malleus and the body of the incus mesially. It terminates below in a depression in the flaccid part of the membrane known as Prussak's pouch. This pouch is the natural path of egress for pus in the outer compartment of the attic through the drum into the external auditory meatus. Infection in this pouch may be reached by curetting the lateral wall of the attic above the drum membrane. It frequently is complicated by osteitis of the ossicles.

On the floor of the main cavity is a deep groove, the *inferior tympanic cavity* (*hypotympanic recess*). A thin layer of bone separates it from the bulb of the jugular vein inferiorly, and from the internal carotid artery anteriorly. Suppuration within the tympanic cavity proper may cause pus to settle in this recess and result in secondary osteitis of the floor, which, in turn, may cause a thrombosis of the internal jugular vein or an ulceration of the internal carotid artery.

CHAIN OF OSSICLES. The three ossicles of the tympanic cavity, the malleus (hammer), incus (anvil) and stapes (stirrup), are arranged in a movable chain which connects the tympanic membrane with the oval window in the vestibule of the labyrinth (Figs. 73, 75, *a*; 75, *b*). The malleus, or outer bone of this chain, is embedded in the substance of the tympanic membrane. It articulates with the second ossicle, the incus, which contacts the stapes, the footplate of which is engaged in the oval window of the vestibule (Figs. 82, 83). The head of the malleus and the body of the incus lie in the epitympanic recess above the upper margin of the tympanic membrane. The handle of the malleus is an important landmark, observed readily in otoscopic examination.

The bones are connected by true joints, lined by synovia. They are bound together with intrinsic ligaments and are secured to the walls of the cavity by extrinsic ligaments covered with mucous membrane. The chain of jointed ossicles constitutes a series of levers by means of which the movements of the drum membrane are transmitted through the footplate of the stapes to the labyrinth. The resulting excursions of the stapes are less extensive and, therefore, more forcible than the movements imparted to the handle of the malleus. Sclerosis and ankylosis of these small bones cause immobilization of the chain and impaired hearing, ever-present dangers in inflammatory lesions of the middle ear.

Two small muscles regulate the tension between the ossicles, one attached to the handle of the malleus, the other to the stapes (Fig. 90, *d*). The *tensor muscle* of the tympanum

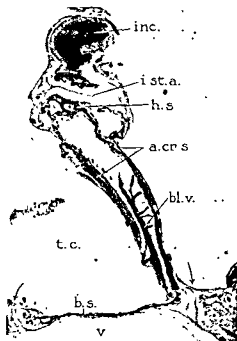


Fig. 82. STAPES, LENTICULAR PROCESS OF THE INCUS AND VESTIBULAR FENESTRA IN A NEWBORN FETUS. PHOTOMICROGRAPH OF A TRANSVERSE SECTION WHICH PASSES THROUGH THE ANTERIOR CRUS. × 17.

As is invariably the case in the late fetus, the child and the adult, the stapes is a fragile ossicle throughout; the head and neck are hollow, the crura are channelled, and the base thinned where these parts face the obturator foramen. Cartilage covers the articular surface of the head, the tympanic and fenestral aspects of the base. The facing surface of the vestibular fenestra (at arrows) is similarly covered by cartilage. Here the anterior crus is sectioned in such a plane as to include blood vessels in the submucosal tissue.

Abbreviations: *a cr.s.*, anterior crus of stapes; *bl.v.*, blood vessel; *b.s.*, base of stapes; *h.s.*, haversian space; *inc.*, incus; *i.st.a.*, incudostapedial articulation; *t.c.*, tympanic cavity; *v.*, vestibule.

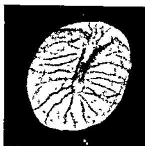


Fig. 80. ACUTE CATARRHAL INFLAMMATION OF THE TYMPANIC MEMBRANE.

Dilated vessels run across the drumhead, and the membrane has lost its gloss. (From Dickie, in Jackson and Coates: The Nose, Throat, and Ear and Their Diseases.)

through the auditory tube to the tympanic cavity.

When the membrane ruptures from concussion from violent pressure transmitted through the air, it usually gives way in the antero-inferior quadrants or around the malleus. Perforations near the attachment of the drum are exceedingly slow in healing.

Perforation of the membrane, which occurs usually in the inferior quadrants, generally is caused by the ulceration of purulent otitis media.

Traumatic perforations of the tympanic membrane will heal more promptly and certainly if the torn edges are splinted by applying a circular piece of cigarette paper moistened with glycerin to prevent the torn edges from curling. Large perforations of the tympanic membrane may sometimes be closed by repeated applications of trichloracetic acid to the margins or by a plastic operation.

TYMPANIC CAVITY

DEFINITION AND TOPOGRAPHIC DIVISIONS. The tympanic cavity lies between the drum membrane and the promontory of the labyrinth of the inner ear (Figs. 84, 85). In the upper reaches of the tympanic cavity, above the level of the drum membrane, is an extremely important, vault-shaped compartment, the *superior tympanic cavity*, or the *epitympanic recess* (*attic*). It contains the head of the malleus and the body of the incus. This recess is continuous, posteriorly, with the mastoid antrum and, an-

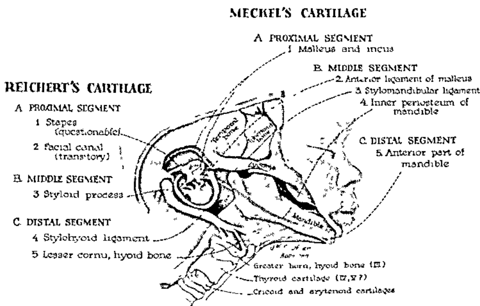


Fig. 81. DERIVATIVES OF THE BRANCHIAL ARCHES, SHOWN IN A DISSECTION OF A FETAL HEAD (AFTER KOLLMANN).

Meckel's cartilage of the mandibular, or first branchial, arch makes 5 contributions to the adult structure of the human head, beginning at its proximal extremity with 2 of the auditory ossicles and ending at the distal extremity with tissue contributed to the mandible in the region of the symphysis. These contributions are listed in the figure, in the successive order of their derivation from "segments" of the cartilaginous bar.

Reichert's cartilage of the hyoid, or second branchial, arch makes an equal number of contributions, but to cervical as well as capital anatomy. The most proximally situated element is the stapes, part of which is so derived; the distal element is the lesser horn of the hyoid bone. The tabular arrangement of derivatives by segments of the cartilaginous arch of the embryo matches that listed for Meckel's cartilage. (From Anson and Bast: Report in preparation.)

remarkable manner from an apparatus that supports the respiratory mechanism in aquatic creatures, the stapes in part and the malleus and incus in their entirety come to serve the acoustic function in man. In addition, the anterior ligament of the malleus, the sphenomandibular ligaments and parts of the mandible are derivatives of the first arch (Fig. 81, list at right); and, similarly, part of the facial canal (in the fetus), the styloid process, the lesser horn of the hyoid bone and the ligament which connects them are derivatives of the second arch (Fig. 81, list at left).

WALLS OF THE GENERAL TYMPANIC CAVITY. The tympanic cavity, a cuboid space, presents a lateral or drum membrane wall, a mesial or labyrinthine wall, an inferior or jugular wall, an anterior or carotid wall, a posterior or mastoid wall, and a superior or cranial wall.

The *lateral wall* of the tympanum is formed partly by the tympanic membrane and partly by the segment of the squamous portion of the temporal bone which forms the upper wall of the external auditory meatus (Fig. 90, *c*). The drum membrane, constituting the main component of the lateral wall, is of such surgical import that it merits separate regional discussion (p. 85).

The *mesial* (*labyrinthine*) *wall* separates the tympanic cavity from the inner ear and presents a point of orientation, the bony capsule of the labyrinth, consisting of the conspicuous rounded *promontory*, formed by the first turn or basal whorl of the cochlea and occupying the middle of the wall (Figs. 84, 90, *d*). The slightly concave tympanic membrane encroaches on the lumen of the main cavity to within 2 mm. of the promontory. Two openings in the mesial wall lead to the labyrinth. The upper opening lies opposite the upper posterior quadrant of the tympanic membrane and is the oval window (fenestra ovalis), into which fits the footplate of the stapes. Directly below, separated from the upper opening by only a few millimeters, is the lower opening, the round window (fenestra rotunda). This is closed by a strong membrane, the secondary tympanic membrane, separating the tympanum from the cochlea (Fig. 84).

Just above the oval window lies the canal for the facial nerve, which passes downward and backward in the posterior portion of the mesial wall. The thin bony lamella which forms the wall of this canal (aqueduct of Fallopius) sometimes presents a defect which leaves the nerve sheath directly in contact with the mucous membrane of the tympanic cavity (Fig. 84). Chronic inflammation of the overlying mucous membrane or mechanical injury from an ill-directed curet may result in paralysis of

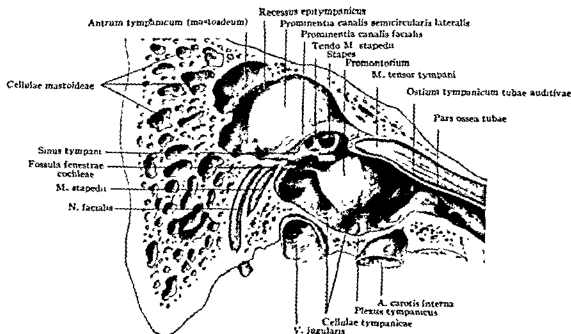


Fig. 84. MEDIAL WALL OF THE RIGHT TYMPANIC CAVITY AND ANTRUM.

draws the membrane mesially and tenses it, simultaneously pulling the handle of the malleus inward. The footplate of the stapes is forced into the oval window and increases the intralabyrinthine pressure. Contraction of the *stapedius muscle* tilts the stapes out of the oval window, decreases intralabyrinthine pressure, and relieves tension on the drum membrane.

The disposition of a mucous membrane sheath over the ossicles, continuous with that lining the tympanic cavity, explains the imminent possibilities of pharyngeal infection involving the tympanic cavity, the associated air spaces, and the tiny ear bones and their delicate joints. The folds of mucous membrane, which extend from the inner wall of the tympanic cavity to the ossicles, often form stiffened adhesive bands after inflammatory conditions in the tympanum; these bands constitute the basis for a serious impairment of hearing. In chronic middle ear disease, involvement of the mucous membrane on the ossicles requires removal of the ossicles themselves as well as the drum. .

The auditory ossicles, certain of their ligaments and associated structures are derived wholly or in part from the branchial skeleton of the embryo. Remodelled, as it were, in a

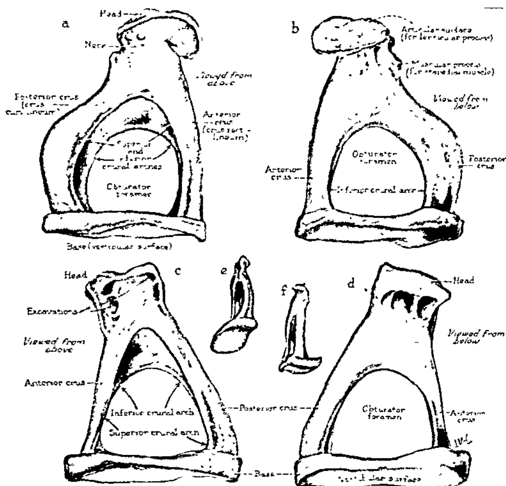


Fig. 83. DRAWINGS OF EXCISED, "CLEANED" SPECIMENS OF ADULT STAPES, SHOWING VARIATIONS IN FORM.

a and *b*, The relatively large head in this specimen is prominently lipped anteriorly, moderately pitted. The neck possesses a nodular elevation for insertion of the stapedial muscle. The superior crural arch is more expansive than the inferior; its outline is roughly triangular, whereas that of the inferior arch is ovoid. Here, as is usually the case, the anterior crus is the more slender of the two and the less curved (hence the term *crus rectilineum*); the posterior crus (*crus curvilineum*) is markedly bowed. The base is upturned circumferentially along the area of lodgment in the vestibular fenestra (oval window).

c to *f*, In this specimen the outline of the head is quadrangular and slightly foveate on its articular surface; the neck and head are deeply pitted. The posterior crus is almost straight. The space of the obturator foramen, as bounded by the crural arches, is increased by the continuous concavity of the head, neck, crura and base. (From Anson and Bast: Laryngoscope, 66: 785-95, 1956.)

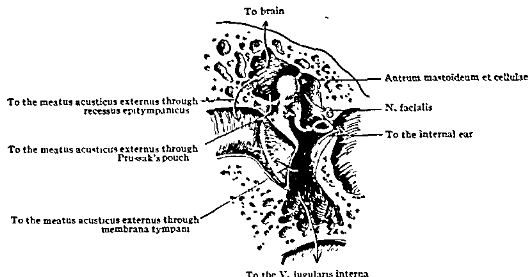


Fig. 85. FRONTAL SECTION THROUGH THE RIGHT MIDDLE EAR TO SHOW THE PATHS OF INFECTION FROM THE TYMPANIC CAVITY.

dren acutely ill from scarlet fever, measles, influenza, pneumonia or other severe infection. Unlike the usual acute suppurative otitis media in which the tissues of the ear return to normal after the infection has subsided, the necrosis and sloughing of tissue in acute necrotic otitis media result in permanent changes, most often in a large permanent perforation of the tympanic membrane. Chronic suppurative otitis media following an acute necrotic otitis media may take one of two forms: a benign type of chronic otorrhea occurs when infection from the external meatus gains access to the mucoperiosteum of the tympanum, resulting in a chronic mucoid discharge; a bone-invading type occurs when stratified squamous epithelium from the external meatus extends inward through a large perforation to line the tympanum, epitympanum and antrum. The desquamation of the cornified outer layers of stratified squamous epithelial cells collects as layered, onion-like masses of whitish debris, filling the antrum and epitympanum. The name cholesteatoma has been applied to this material because of its content of cholesterol crystals and the tumor-like gradual enlargement of the mass as additional layers of desquamated cells are added. Bone erosion around a cholesteatoma eventually exposes the periotic labyrinth, the facial nerve, the dura of the middle or posterior cranial fossa, or the wall of the sigmoid sinus. The cholesteatoma debris is nearly always infected with putrefactive and pathogenic organisms from the meatus, producing a foul, purulent discharge and carrying the threat of suppurative extension into adjacent structures. Chronic suppurative otitis media with cholesteatoma is therefore considered a dangerous, bone-invading process requiring surgical correction.

A cholesteatoma may also develop in the epitympanum in the presence of an intact tympanic membrane as the result of an invagination of the pars flaccida, producing a pocket above the short process which fills with desquamated epithelial cells. Such a cholesteatoma is termed "primary acquired cholesteatoma" to differentiate it from the previous variety that is secondary to an acute necrotic otitis media.

AUDITORY (EUSTACHIAN) TUBE

DEFINITION, BOUNDARIES AND PHYSIOLOGY. The auditory (eustachian) tube, commonly considered to be a portion of the middle ear, is an osteocartilaginous duct connecting the tympanic cavity with the nasal portion of the pharynx (Fig. 85). Its mucous membrane lining is continuous with that of the communicating tympanum and pharynx. Through this passage the air pressure on both sides of the tympanic membrane is equalized, a factor essential to proper function of the membrane. Obstruction to the entrance of air into the tube results in a negative pressure in the tympanic cavity, which, with the atmospheric pressure on the outer side of the drum, causes the membrane to be retracted into the cavity. Otoscopic ex-

the facial nerve. Above and behind the canal for this nerve is the entrance (aditus) to the mastoid (tympanic) antrum.

The *inferior wall* or floor of the cavity is a thin-walled groove which sinks below the level of the tympanic membrane and the opening of the auditory tube, forming the hypotympanic recess. This cavity favors the collection of pus from middle ear disease. Pneumatic spaces frequently lead off from this region, forming the cells of the tympanum. The bulb of the jugular vein may encroach on the floor of the tympanum and produce a domelike elevation in which dehiscence occasionally occurs.

The large, bell-like opening of the auditory tube is located in the *anterior wall* (Fig. 84). The internal carotid artery encroaches on the tympanum in this region, from which it is separated by a thin plate of bone. The thinness of this bony interval accounts for the distressing auditory symptoms of which patients with carotid aneurysm complain. Infection here may extend to the adjoining cavernous sinus and cause thrombosis. Fractures frequently occur through this wall.

The *posterior* or *mastoid wall* in the upper or epitympanic portions leads into the mastoid antrum by way of the aditus (Fig. 84).

A thin plate from the squamous portion of the temporal bone, which itself is often paper-thin, separates the *superior wall* of the cavity from the temporal lobe of the brain and its enveloping meninges. This plate, called the tegmen, continues posteriorly as the roof of the antrum. The petrosquamosal suture passes diagonally through the tegmen. This, in the young, transmits blood vessels and lymphatics from the middle ear to the middle cerebral fossa. It may be so broad as to present an extensive dehiscence in the wall, where the mucosa of the cavity is in direct contact with the dura. Certain meningeal and cerebral complications of otitis media may be accounted for in this way.

Surgical Considerations

Congenital or acquired absence of one or more of the ossicles results in a serious hearing impairment of the conductive type. Otosclerotic ankylosis of the stapes is the most frequent cause for progressive conductive deafness in young and middle-aged adults. Various surgical procedures are available to reconstruct an interrupted ossicular chain, to mobilize an ankylosed stapes, or to create a new fenestra to take the place of an oval window occluded by stapes ankylosis. These operations are variously known as tympanoplasty, stapes mobilization and the fenestration operation.

ACUTE MIDDLE EAR DISEASE. Acute secretory or catarrhal otitis media is caused by an occlusion of the eustachian tube. This may be caused by hypertrophied pharyngeal adenoids, by allergic edema, by an acute nasopharyngitis or by tumor. Occlusion of the tube results in a negative pressure as first the oxygen and then the nitrogen of the contained air is absorbed and finally replaced by a transudate. The resultant impaired hearing of the conductive type can be restored by removal of the obstruction and by inflation of the eustachian tube.

Acute suppurative otitis media is caused by the spread of infection from the nasopharynx along the auditory (eustachian) tube into the middle ear (Fig. 85). The mucoperiosteum of the middle ear becomes inflamed, followed by formation of purulent exudate causing the tympanic membrane to bulge outward with severe pain, fever and a conductive hearing impairment. Drum perforation follows, preceded by pathologic infiltration of its layers with destruction of part of the fibrous tissue framework.

The mucous membrane of the pneumatic cells of the mastoid process is probably involved in every otitis media of any severity. If the infection is virulent, the pus in the mastoid cells causes decalcification and partial destruction of the bony cell partitions, resulting in abscess formation and acute coalescent mastoiditis. The progressive bone destruction may eventually allow the pus to escape by perforation of the outer cortex to form a subperiosteal abscess. However, it may first burrow through the inner table of the skull to produce an intracranial abscess or meningitis; therefore an acute coalescent mastoiditis is a condition requiring surgical evacuation of pus.

CHRONIC MIDDLE EAR DISEASE AND CHOLESTEATOMA FORMATION. Chronic middle ear suppuration may be the end result of a severe acute suppurative otitis media of the necrotic type with necrosis of large areas of the tympanic membrane, sometimes including necrosis and sloughing of the mucoperiosteum of the middle ear, portions of the ossicles and, rarely, of areas of bone. Acute necrotic otitis media occurs almost exclusively in young chil-

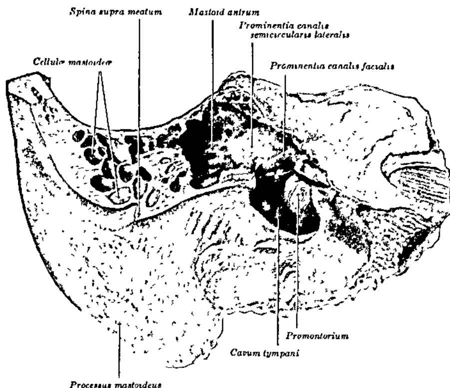


Fig. 86. LATERAL VIEW OF THE RIGHT TYMPANIC CAVITY AND ITS MASTOID EXTENSIONS.

These are exposed by removing their outer wall and contiguous portions of the anterior and superior walls. (Shambaugh, in Jackson and Coates: The Nose, Throat, and Ear and Their Diseases.)

the aditus ad antrum; second, a cavity, usually more extensive than those behind it, called the mastoid antrum; and third, small diverticula of the antrum, the mastoid air cells proper. The mastoid antrum or original mastoid cell is present at birth, and the remaining mastoid cells evaginate from it in early life. These appendages of the tympanic cavity are lined by mucous membrane.

ADITUS AD ANTRUM. The aditus ad antrum, or entrance into the antrum, is a relatively broad, short canal of variable dimensions, which places the mastoid antrum and air cells in communication with the tympanic cavity. The shallowness of this communication is accounted for in large part by the lifting up of the floor of the antrum by the facial ridge, which contains the seventh (facial) nerve and a small artery. On the *medial wall* of the aditus (Fig. 84), above and behind the facial ridge, is a smooth, convex area of bone marking the position of the lateral semicircular canal of the inner ear. Any obstruction of the narrow entrance favors the retention of inflammatory products in the mastoid air cells. For this reason, removal of the *external wall* of the aditus is one of the most important steps in the procedure designed to place the mastoid air cells and antrum into broad and open communication with the tympanic cavity.

MASTOID (TYMPANIC) ANTRUM. The mastoid antrum is a large mastoid air cell, formed before birth by upward and posterior extension of the tympanic cavity (Figs. 85, 86). The remaining cells of the mastoid cavity develop from this cell and remain in communication with it by orifices in the antral walls. In general, the antrum lies behind and above the bony portion of the external auditory meatus, but its location and size vary between wide limits; these variations are of the greatest surgical importance. In the newborn the antrum lies higher than in the adult, being almost directly above the bony auditory meatus, on a level with its upper margin. As the mastoid bone develops, the antrum moves progressively backward and downward. It holds a fairly constant relationship to the suprameatal spine (of Henle). In the infant the bony wall separating the antrum from the exterior is not more than

amination in this condition reveals foreshortening of the long process, prominence of the short process, thickening of the drum, and distortion or absence of the light reflex. If the obstruction persists, the sensation of fullness of the ear results. Permanent changes in the drum occur from hyperemia and fibrosis with scar formation. The scar formation involves the ligamentous structures of the ossicles, causing a semi-ankylosis of the bones, which is, by far, the most common cause of deafness. This is the so-called catarrhal deafness.

Anatomic Summary. The auditory tube is about 3.5 cm. long, and is directed downward, mesially, and forward from the tympanic cavity. Structurally, the wall is divided into bony and cartilaginous portions. The bony wall extends about a third of the length of the tube from the tympanic orifice to the pharynx. Its shape is that of two elongated cones, a pharyngeal and a tympanic, placed together at their truncated summits. The lumen of the duct, therefore, is widest at the two orifices and is narrowed at the junction of the bony and cartilaginous portions. This narrowing, known as the *isthmus*, is from 1 to 2 mm. in diameter, a fact which predisposes to obstruction from congestive swelling of its mucous membrane lining. A long-standing infection may produce scar formation with permanent constriction, so that the tube will not admit a catheter or bougie much larger than 1 mm. in diameter. It is a question, however, whether such a procedure, because of the trauma produced, does not aggravate the condition toward which therapy is directed.

The *pharyngeal orifice* is located on the lateral wall of the nasopharynx about 1 cm. behind the posterior extremity of the inferior concha (Fig. 75, *d*).

Surgical Considerations

Obstruction of the Auditory Tube. Auditory tube obstruction is caused primarily by inflammation of the lymphoid ring under the mucous membrane lining its pharyngeal orifice. Generally, the edema results from an inflammatory extension along the mucous membrane from some focus in the nasopharyngeal tract. The mucous membrane of the pharyngeal orifice of the tube may be involved by adjacent adenoid tissue. The occlusion which follows produces negative pressure within the tympanum, passive congestion, and connective tissue formation. It may bring about deafness by causing scar tissue to be formed over the joints of the ossicles, which cuts off the innervation and blood supply and limits mobility.

The pharyngeal orifice may be injured during operations in the nasopharynx or on the posterior ends of the turbinate bones, mainly in the unguarded curettage of adenoids, so as to result in scar formation which brings about occlusion of the orifice. This scar formation may be so extensive, or be so located, as to involve the superior and middle constricting muscles, contracting the tubal opening and leaving the orifice permanently open. The scar has little resistance to infection.

Inflation of the Tympanic Cavity. Inflation of the tympanic cavity for diagnostic, prognostic or therapeutic purposes can be accomplished only through the auditory tube. Valsalva's procedure consists in a vigorous expiratory effort with the nose and mouth held closed. Contained air, having no other means of escape, is forced into the auditory tubes and into the tympanic cavity. In the normal ear this produces a sense of pressure with dulled hearing as the intratympanic air pressure becomes greater than the pressure in the external auditory canal. In pathological occlusion of the eustachian tube the hearing is improved as the air enters the middle ear, relieving the negative pressure. Inflation of the eustachian tube may also be accomplished by the Politzer method or by catheterization. This procedure should be done only under the direction of a skilled otologist. Politzer's method of inflation is by the application of a blast of air to the nostril from a rubber bag or a source of compressed air, while the opposite nostril is held closed and the patient swallows. The act of swallowing closes the palate and at the same time opens the eustachian tube. Care must be taken not to burst an atrophic tympanic membrane.

MASTOID ANTRUM AND MASTOID AIR CELLS

The mastoid (tympanic) antrum and the mastoid air cells are the second division of the air-containing compartments of the middle ear (Fig. 86). By the antrum and mastoid air cells are meant the diverticula of the tympanic cavity formed at the expense of the mastoid portion of the temporal bone. Extending backward from the epitympanic recess of the tympanic cavity are, first, a narrow bony opening called

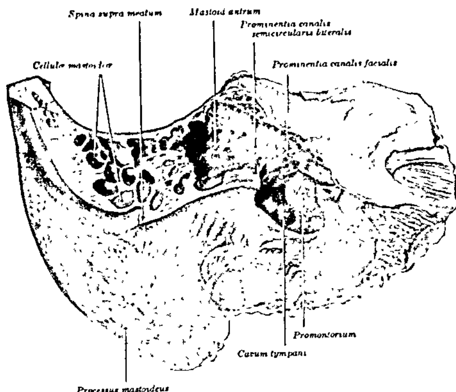


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2 to 4 mm. in thickness; as age advances, the lateral plate may attain a thickness of 1 to 1.5 cm.

The *lateral* (*external*) *wall* of the antrum is the wall of surgical approach, which, projected externally, is that part of the temporal bone underlying the auricle. In the adult it is about 1 to 1.5 cm. thick. The *posterior wall* opens into mastoid air cells separating it from the lateral sinus, which is slightly inferior, as well as posterior, to it. The *mesial wall* is composed of the mastoid cells in the sclerosed portion of the petrous part of the temporal bone. On this mesial wall, deep in and a little anterior, lie the lateral (horizontal) semicircular canal and the canal for the facial nerve. The mesial wall of the antrum is well anterior to a normally placed lateral sinus. The *superior wall* or *roof* of the antrum lies against the middle cerebral compartment; osteitis of this wall may cause a subtemporal abscess. An incision above the line of the roof or above the line of the suprameatal spine (of Henle), projected internally, enters the cranial cavity. The anterior portion of the *inferior wall* is in close relation with the seventh (facial) nerve, which, in its bony canal, descends vertically through the mastoid bone; the nerve leaves the stylomastoid foramen, after having wound about the posterosuperior margin of the tympanic cavity and around the lateral semicircular canal into the floor of the antrum. The *anterior wall* presents an opening into the tympanic cavity through the aditus.

Mastoid Air Cavities. The air spaces of the mastoid process are not present in the newborn. Toward the end of fetal life the antrum sends out buds or trabeculae into the spongy tissue between its two bony tables; these are the progenitors of the mastoid air cells. These buds enlarge and divided secondarily until they ramify, with great individual variation, throughout the mastoid portion of the temporal bone, even into the squamous part of the temporal bone and into the occipital bone and the zygomatic process. As the margin of the mastoid process is approached, the cells tend to become larger, the tip usually being occupied by one or several large cells (Figs. 84, 86).

Infection of the mucoperiosteum of the tympanic cavity is usually accompanied by simultaneous infection of the mucoperiosteum of the pneumatic cells of the antrum and adjacent pneumatic cells. Where these cells are close to the surface, as in the mastoid tip, tenderness occurs, especially in children, in whom the bone is thin. Tenderness over the mastoid early in an otitis media does not indicate a process requiring surgical intervention. Tenderness in an acute otitis media that has drained for several weeks is an indication of a coalescent mastoiditis which may require surgical intervention.

Types of Mastoid Structure. Four types of mastoid bone may be differentiated: pneumatic, diploic, sclerotic and mixed (Fig. 87). In the *pneumatic* type there is complete development of cell structure, and the whole mastoid process is composed of large air spaces communicating with each other and with the antrum. The cortex is relatively thin and perforates early in disease, especially in children. Danger of intracranial complication, particularly if the location of the inflammation is external, is reduced to a minimum. In the *diploic* type the mastoid process conforms to the structures of the other cranial bones, having an outer and an inner table with diploe between. The antrum usually is the only cell present. The cortex is thick and does not present localizing symptoms of mastoid disease. The *sclerotic* type is that in which the mastoid process is composed of compact bone of extreme density, the result of chronic infection which has interfered with the usual absorption of diploe and subsequent pneumatization and has brought about a condensing osteitis resulting in nondevelopment or complete obliteration of the cell system. The antrum remains, although frequently reduced in size. The almost acellular mastoid bone usually is of the consistency of ivory. The improbability of localizing symptoms of mastoid disease, presenting themselves in such circumstances, is evident. Infection follows the line of least resistance and may invade the middle or posterior cranial fossa, lateral sinus or lateral semicircular canal. The *mixed* type represents a combination of the diploic and sclerotic types, with perhaps a few pneumatic cells present. An index of the type of mastoid upon which operation is contemplated may be obtained by roentgenologic examination.

Suprameatal Triangle, Spine and Fossa; Relations to the Mastoid Antrum. The outer surface of the mastoid process has few conspicuous landmarks. The *posterosuperior margin* of the opening of the bony meatus usu-

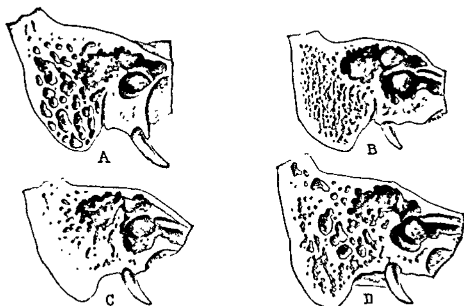


Fig. 87. VARIETIES OF PNEUMATIZATION OF THE MASTOID PROCESS, AND TYPES OF MASTOID AIR CELLS.
A, Pneumatic type; *B*, diploic type; *C*, sclerotic type; *D*, mixed type.

ally is a conspicuous marking. Within its border, or just adjacent to it, is the more or less prominent *suprameatal spine* (of Henle), to which the superior ligament of the auricle is attached (Fig. 88).

The outer opening of the bony meatus is oval in outline, with its long diameter vertical. At the level of the superior margin of the opening, the posterior root of the zygoma, the *suprameatal crest*, runs horizontally backward. The original *suprameatal triangle*, as described by Macewen, has, as one side, the posterior root of the zygoma; as a second, the posterosuperior margin of the opening of the bony meatus with its contained suprameatal spine; and, as a third, a line joining the two other sides. In the floor of the triangle lies the *suprameatal fossa* (Fig. 88). These landmarks are not always easy to outline definitely in an operative field.

Another description gives as one side of the

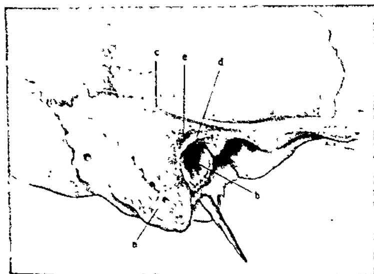


Fig. 88. BONY LANDMARKS INVOLVED IN MASTOID OPERATION.
a, Mastoid process of the temporal bone; *b*, the bony part of the external auditory canal; *c*, suprameatal crest; *d*, suprameatal spine; *e*, suprameatal fossa. (From Bickham: Operative Surgery.)

suprameatal triangle a horizontal line tangent to the superior margin of the bony meatus; as a second, a vertical line passing tangent to the posterior margin of the bony meatus; and as a third, a line formed by the posterosuperior margin of the canal wall. This triangle, while actual, calls for considerable dissection if it is to be determined accurately.

Since the posterosuperior margin of the canal wall can be determined readily, it may be used as a base for an equilateral triangle which may be constructed in the imagination, no other landmark being necessary.

The *mastoid antrum* lies deep to the suprameatal fossa and, therefore, directly within the suprameatal triangle or just behind it; in other words, it lies halfway up the posterior wall of the meatus between the suprameatal spine and the posterior portion of the horizontal suprameatal crest. The suprameatal crest marks the inferior edge of the dura, the roof of the antrum, and the middle cerebral fossa. Incisions must be kept below this crest to avoid injury to the middle cerebral fossa, which sometimes dips to an extremely low level. When the suprameatal crest cannot be felt, incisions should be kept below a horizontal line running backward from the upper edge of the bony external meatus or its most prominent part, the suprameatal spine (of Henle). An instrument in the antrum must be checked from going deeper to avoid injury to the lateral semicircular canal and the facial nerve.

Surgical Considerations

MASTOIDITIS. The mucoperiosteum of the pneumatic cells of the mastoid process is involved to some degree in almost every acute suppurative otitis media, but this is not generally considered a clinical mastoiditis. When the accumulation of pus in the mastoid cells is accompanied by decalcification and absorption of the bony cell partitions causing their coalescence into a large abscess cavity, the condition is termed clinical, coalescent or surgical mastoiditis. Surgical mastoiditis is always secondary to an acute otitis media and has become rare since the advent of the sulfonamide drugs and antibiotics. Surgical mastoiditis rarely develops in less than two weeks after the onset of acute otitis media. The symptoms of surgical mastoiditis are continuation of a purulent discharge for more than three or four weeks in an acute otitis media; pain, especially nocturnal, in an ear which has drained for several weeks; periosteal edema over the mastoid process with tenderness in an ear which has drained for several weeks; and sagging of the posterosuperior meatal wall due to edema of the periosteum adjacent to the antrum. Roentgen studies will show decalcification and loss of distinctness of the cell partitions.

PATHS OF EXTENSION OF MASTOID INFECTION. Although infection of the *lateral sinus* may arise from infection of the superior petrosal sinus as a result of inflammation of the attic of the tympanic cavity or, in children, by involvement of the jugular bulb from infection through the floor of the tympanic cavity, it usually arises from suppurating mastoid cells. It is the sinus most commonly involved because of its relations to so large a series of diseased cavities. Extension occurs by way of the numerous small veins that reach the sinus through the bone, and by direct infection arising from perisinus abscess. With the lateral sinus involved, extension may occur to associated venous channels, especially the internal jugular vein, or to the other side of the skull by way of the confluens sinuum. The lateral sinus runs horizontally forward from the confluens to a point 1.5 cm. behind, and slightly inferior to, the antrum, at which point it turns downward and forward, forming what is known as the elbow of the sinus (Fig. 89). It ends at the jugular foramen as the internal jugular vein. Its descending portion has relations with the posterosuperior angle of the suprameatal triangle. In the pneumatic type of mastoid the sinus runs in a shallow groove on the mesial aspect of the temporal bone, and is more mesial and more posterior than in sclerosed and allied types of mastoid bone. In the sclerosed type the sinus almost canalizes the bone and runs near the antrum and the posterior wall of the external auditory meatus.

Mastoid disease may extend to the *meninges* and *brain* (Fig. 89). Inflammation may extend upward through the roof of the antrum and the superior mastoid cells contained in that wall. By this route it may extend through the small vascular channels and cause extradural abscess, localized or general meningitis, or brain abscess. Most of this disturbance is seen in the posterior cranial fossa.

It should be borne in mind that the facial canal with the enclosed *facial nerve* arches backward over the oval window and descends

Fig. 89. RELATIONS OF THE MASTOID ANTRUM TO THE TEMPORAL LOBE AND THE TRANSVERSE SINUS.

almost perpendicularly, in relation to the lateral semicircular canal and the floor of the antrum. Cholesteatoma following chronic middle ear disease may cause destruction of this nerve with resultant facial palsy. This results in complete immobility of the muscles of expression on the affected side of the face.

In the pneumatic mastoid, infection readily finds its way into the contiguous cells, causing early *perforation of the cortex*. It may penetrate the inner aspect of the mastoid tip, burst through the sternocleidomastoid muscle, and break into the submaxillary region of the neck, producing what is known as Bezold's type of mastoiditis, which may be confused with involvement of the glands of the posterior cervical triangle so far as swelling and tenderness are concerned.

SIMPLE MASTOID OPERATION. The simple mastoid operation is rarely required today and then usually in patients with a neglected acute otitis media who have not received adequate antibiotic therapy. The operation consists in opening and draining the mastoid antrum and air cells, and clearing a passage to the middle ear. A single incision about 0.5 cm. behind the attachment of the auricle is made through the overlying tissues and periosteum. The auricle and the membranous meatus are pushed forward, and the periosteum is stripped backward from the mastoid bone. In the anterosuperior part of the wound the suprameatal spine (of Henle) and the posterior boundary of the external auditory meatus are exposed, and the cortex of the mastoid is removed below the posterior continuation of the suprameatal spine. The spine should be allowed to remain intact to serve as a landmark for any later operation on the mastoid area. The cells overlying the antrum are sought, the antrum is entered, and the mastoid cells are curetted, with the antrum as a center of operation.

RADICAL MASTOID OPERATION. The radical mastoid operation is performed for chronic suppurative otitis media of the bone-invading type, usually with cholesteatoma formation. The purpose of the operation is to exteriorize the cholesteatoma cavity so that the progressive erosion of bone caused by the retained desquamated debris will no longer continue. The exteriorization is accomplished by removing the bone lateral to the antrum and epitympanum, converting these cavities into a common cavity with the external auditory meatus. In the classical radical operation remnants of the tympanic membrane and ossicles are also removed. In the modified radical mastoid operation remnants of the tympanic membrane and ossicles that do not overlie extensions of cholesteatoma may be left in situ so as to preserve hearing. The radical mastoid operation is generally performed by the endaural route,

affording a more direct access to the diseased area than the postaural incision.

INTERNAL EAR

In the petrous portion of the temporal bone, mesial and posterior to the tympanic cavity, lies the internal ear or labyrinth; this has two distinct functions, cochlear or sound perception, and vestibular or equilibration and orientation. The internal ear consists of a bony labyrinth which encloses the highly complex membranous labyrinth (Figs. 90 to 93). In most areas the membranous labyrinth is not in contact with its bony case, but is surrounded by fluid known as perilymph. The membranous labyrinth is filled with a fluid known as endolymph, which is not in communication with the perilymph. Both the acoustic and the equilibratory nerve paths arise from the membranous labyrinth. Exact knowledge of the labyrinth and its projection on the tympanic cavity is clinically important because of the possibility of its injury in operations upon the tympanic cavity and antrum. The walls of the cavity may be eroded by cholesteatoma, and occasionally they are injured by the curetting of granulations.

Osseous Labyrinth. The bony capsule of the labyrinth, 2 to 3 mm. wide, is a hard, ivory-like structure, embedded in the petrous pyramid of the temporal bone. It is long-resistant to pus in suppurative otitis media. In this

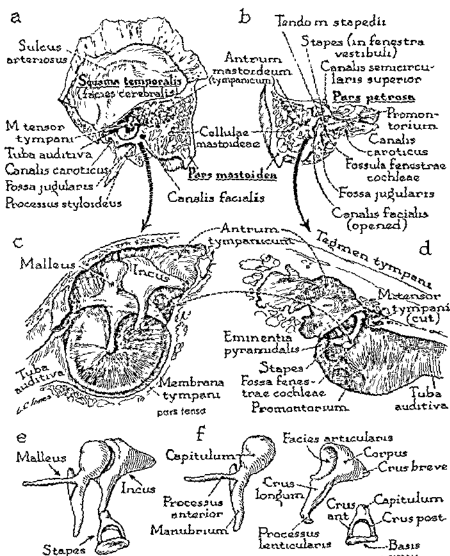


Fig. 90. TYMPANIC CAVITY OF THE EAR, WITH AUDITORY OSSICLES AND RELATED SPACES, EMINENCES AND TYMPANIC (DRUM) MEMBRANE.

a and *b*, Temporal bone cut through the long axis of the tympanic cavity. *c* and *d*, Details for the areas indicated in the figures above. *e*, Auditory ossicles in their articular relationship. *f*, Ossicles separated.

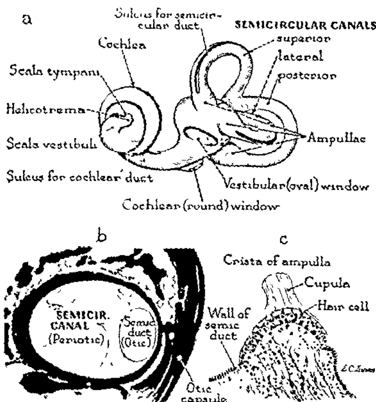


Fig. 91. SEMICIRCULAR AND COCHLEAR CANALS AND THE SEMICIRCULAR DUCT OF THE EAR.
a, Perilymphatic (periotic) labyrinth shown as a cast. *b*, Semicircular canal (of the periotic, or perilymphatic, labyrinth) and the contained duct (of the otic, or endolymphatic, labyrinth). *c*, Crista of an ampulla in a semicircular duct.

labyrinth are distinguished four portions: a middle or vestibular portion, a posterosuperior or semicircular canal portion, an anterior or cochlear portion and the internal auditory canal.

The middle portion, or vestibule, of the bony labyrinth is oval (Fig. 91, *a*). On its lateral, or tympanic, wall is the fenestra vestibuli (closed by the base of the stapes); on the medial wall are located small recesses from which, through minute foramina, filaments from the saccule, the utricle, the ampullae of the semicircular ducts, and the cochlea pass to the auditory nerve in the internal acoustic meatus. The vestibule communicates behind with the semicircular canals, and in front with the cochlea. In addition to the foramina which transmit nerve filaments from the vestibule to the internal acoustic meatus, a single and more capacious canal, termed the vestibular aqueduct, leaves the vestibule on the posterior wall of the latter. This aqueduct, in which are lodged the endolymphatic duct and proximal part of the sac, passes backward through the petrous part of the temporal bone, to terminate beneath the dura mater on the anterior wall of the posterior cranial fossa. The opening, directed downward and of slitlike form, is situated midway between the internal acoustic meatus and the sulcus for the sigmoid venous sinus.

The three semicircular canals open into the vestibule, not by six, but by five apertures—since the superior and posterior canals unite to form the crus commune. Each canal forms approximately two thirds of a circle, and each is singly ampullated to accommodate a corresponding dilatation in the contained semicircular duct (Figs. 91, *a*; 92, *a*).

The cochlear part of the osseous labyrinth is unlike the canalicular division in three important respects: It is single, not a set of channels; its form is not that of a divergent group of canals, but is that of a snail shell, with a central core, termed the modiolus; its space, unlike that of any one of the three semicircular canals, is divided incompletely into two passages—an upper scala vestibuli and a lower scala tympani—by an osseous spiral lamina which winds round the modiolus like

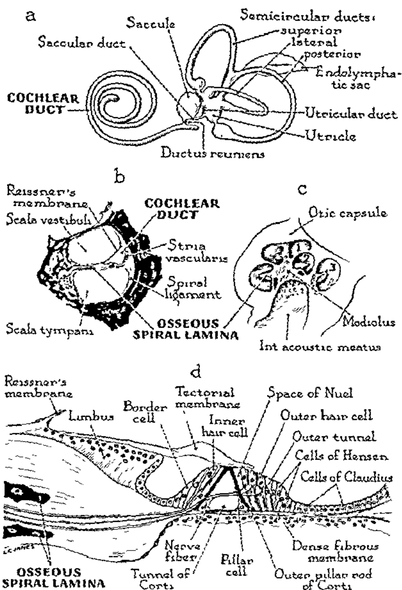


Fig. 92. SEMICIRCULAR AND COCHLEAR DUCTS, AND THE ORGAN OF CORTI.

a, Endolymphatic (otic) duct system; from a reconstruction. *b*, Cochlear scalae (or periotic, or perilymphatic, labyrinth) with the contained cochlear duct (of the otic, or endolymphatic, labyrinth). *c*, Section through the osseous cochlea with the turns numbered; from a sectioned bone. *d*, Organ of Corti (Reissner's membrane removed).

the thread of a screw (Fig. 92, *c*). The spiral lamina actually consists of two matching plates of bone between which are situated channels for transmission of fibers of the cochlear nerve (Fig. 92, *d*). The channels then pass downward in the modiolus; they finally open on the wall of the *internal acoustic meatus, in a spiral* series of minute orifices. A membrane, termed the basal lamina, extends from the free edge of the osseous spiral lamina to the outer wall of the cochlea; in so doing, it completes the division of coiled cochlea into the two scalae. However, the scalae communicate at the apex, or cupola, of the cochlea. The scala tympani begins, at the base of the cochlea, at the fenestra cochleae, the orifice of which on the medial wall of the tympanic cavity is closed by the secondary tympanic membrane (Fig. 91, *a*). Near the point where the scala tympani originates from the vestibule, a short canal, the cochlear aqueduct, extends downward through the petrous *part of the temporal bone to end in the jugular* fossa. Through it the perilymphatic space is brought into communication with the subarachnoid space.

Perilymphatic Space and Membranous Labyrinth. The membranous labyrinth lies within the bony labyrinth and, save where it is attached to the bony walls by fibrous bands, especially at the exit of the nerve fibers, is sur-

rounded on all sides by fluid, the perilymph (Fig. 92, *b*).

The perilymph within the *perilymphatic space* conducts the least modification of pressure to all parts of the stream, and possibly has a direct communication with the subarachnoid spaces of the brain, both by way of the aqueduct of the cochlea and by the sheaths of the auditory nerves. The membranous labyrinth contains fluid known as the endolymph. Since pressure in this space is equalized, changes in position in different movements of the head are transmitted at once to the sensory cells in connection with the vestibular branch of the auditory nerve.

The membranous otic labyrinth, in its canalicular and cochlear portions, repeats, but in lesser caliber, the form of the space within the bony (periotic) labyrinth (Fig. 92, *a*). In the vestibular portion, however, their form differs, since the vestibule contains two membranous chambers, the utricle and the saccule. In addition, the vestibule contains either the proximal parts or all of the ducts which bring the two chambers into communication either with each other or with the cochlear duct and the endolymphatic sac; these are the saccular, utricular and endolymphatic ducts, and the ductus reuniens.

The saccule is oval and occupies the lower and anterior parts of the vestibule. On the anterior wall is found the macula of the saccule, in which terminate fibers of the auditory nerve. From its lower part a short canal—the ductus reuniens—descends and widens into the cochlear duct; from its anterior part a second small channel—the saccular duct—extends toward the utricle, where, joining the duct from the utricle, the common channel enters the vestibular aqueduct as the endolymphatic duct.

The utricle, larger than the saccule, occupies the upper and superior parts of the vestibule. Like the saccule, the utricle is oval and is provided with a sensory area, the macula of the utricle. The six openings on the walls of the utricle differ in form and size from the two by which the saccule communicates with related chambers: The orifice of the utricular duct, unlike that of the saccular duct, is an elongated slit guarded by a valvelike fold, formed by the approximated walls of the utricle and the expanded part of the endolymphatic duct (Fig. 93, *a*, *b*). The orifices of the ampullae of the three semicircular ducts, and those of the nonampullated end of the lateral duct and of the common crus, are all larger than the ductus reuniens.

The endolymphatic duct, formed by conjunction of the utricular and saccular ducts, begins in a considerable dilatation, or sinus; then, as it is carried through the vestibular aqueduct, the channel narrows into an isthmus, and next widens into the sac, the walls of which are rugose (Fig. 93, *b*, *c*; compare Fig. 93, *a*). The endolymphatic sac is prolonged beyond the cranial orifice of the vestibular aqueduct. Lying on the posterior wall of the petrous pyramid, often in a fovea, it is lodged in meningeal tissue.

The cochlear part of the membranous labyrinth is formed by the cochlear duct, or scala media. In cross section the duct is triangular (Fig. 92, *b*). Near its beginning the cochlear duct is united with the saccule by the ductus reuniens; it terminates blindly at the apex of the osseous cochlea. The duct is spirally turned between the scala vestibuli and the scala tympani. Its position between the vestibular and tympanic scalae is peripheral, the outer wall being attached to the periosteal lining of the cochlear canal. The wall which is directed obliquely toward the apex of the cochlea is exceptionally thin; it is formed by membrana vestibularis (Reissneri). The third wall of the triangular duct is directed toward the base of the cochlea, to the plane of which it is parallel. It consists of a plate of connective tissue, the lamina basilaris, which extends from the free margin of the osseous spiral lamina to the outer wall of the bony cochlea, where it becomes continuous with a ridgelike projection of the periosteum, termed the ligamentum spirale cochleae. The lamina basilaris supports the organon spirale (Corti), the epithelial structure in which terminate the fibers of the cochlear nerve (Fig. 92, *d*).

The canalicular part of the membranous labyrinth consists of three epithelial tubes lying within the bony canals; the ducts correspond to the osseous canals in arrangement and course, but are everywhere smaller (Fig. 91, *a*). Each of the three semicircular ducts differs from the cochlear duct in four important respects: each duct has the form of an incomplete oval rather than of a spiral; the semicircular duct is round in cross section (Fig. 91, *b*), whereas the cochlear duct appears triangular when comparably cut; each semicircular duct

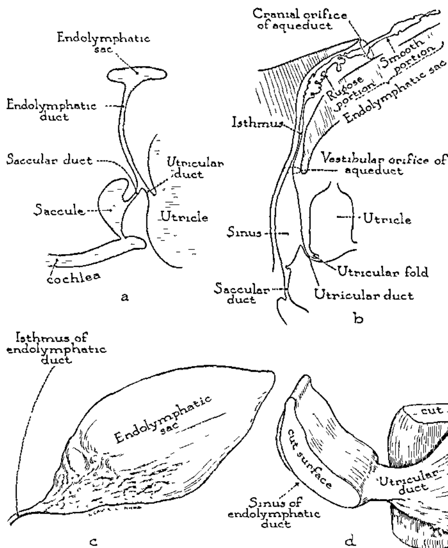


Fig. 93. FORMS OF THE HUMAN ENDOLYMPHATIC DUCT AND SAC AND OF THEIR COMMUNICATING CHANNELS.

a, Conventional concept. *b*, Concept of Bast and Anson, schematic. *c*, Endolymphatic sac in the child, showing rugosities (Bast; from a reconstruction). *d*, Sinus of the endolymphatic sac, utricle and utricular duct in the child (Anson, Wilson and Nesselrod; from a reconstruction).

lies within an unpartitioned perilymphatic (periotic) space, whereas the cochlear duct is situated between, and serves partially to subdivide the perilymphatic space into scalae (tympanic and vestibular); within each semicircular duct the sensory mechanism is limited to the semilunar crista in the ampullary enlargement at the vestibular extremity of the duct (Fig. 91, *c*), while in the cochlear duct the sensory apparatus (the organ of Corti) extends uninterrupted from the basal to the apical limit of the cochlea in spiral form.

Blood Supply of the Labyrinth. An interest in the blood supply of the labyrinth has arisen because of its bearing on clinical otology. The Ménière syndrome, sudden occurrence of deafness and vertigo, is probably dependent upon some circulatory disturbance, possibly hemorrhage into the labyrinth. The questions of extension of infection from the middle ear to the labyrinth and of extension of labyrinthine infection into the cranial cavity deal, in large measure, with vascular complications.

The sole arterial supply of the internal ear is the *internal auditory artery*, a branch of the basilar artery, which enters the labyrinth through the internal acoustic canal. Its branches are end arteries and constitute the sole supply for definite areas. The first branch is given off in the internal acoustic canal. It is the cochleovestibular artery, supplying part of the cochlea and part of the vestibular apparatus. This branch divides into two trunks, one supplying the proximal two thirds of the basal whorl of

the cochlea, and the other running backward as the posterior vestibular artery.

The continuation of the internal auditory artery divides again into two trunks, one of which penetrates the modiolus and furnishes the arterial supply for all the cochlea save the proximal two thirds of the basal whorl, the other of which runs backward as the anterior artery of the vestibule. Continuation of the anterior cochlear artery supplies portions of the semicircular canals.

Shambaugh points out the clinical bearing which attaches to the branching of the labyrinthine artery. Since the organ of Corti, through the entire length of the basal whorl, is supplied by minute terminal end-arteries, it becomes apparent that disturbances in these separate terminal twigs should be capable of disturbing the function of definite circumscribed areas of Corti's organ. It is possible for an embolus to lodge in the main trunk and to destroy completely the function of the vestibular and cochlear mechanisms. An embolus which lodges in the cochleovestibular vessels disturbs the function in the proximal two thirds of the basal coil of the cochlea, that portion which has to do with the perception of tones toward the upper end of the tone scale. At the same time there occur disturbances of equilibrium in the domain of the semicircular canals. An embolus lodging in a continuation of the labyrinthine artery should suppress perception of the lower tones, which are taken up by the nerve cells in the upper coils of the cochlea. This embolus should produce a profound derangement in equilibrium through disturbance of portions of the superior and lateral semicircular canals.

Sensory Paths of the Auditory Nerve. The eighth (auditory) nerve, with its meningeal coverings, extends into the internal auditory canal and divides into its terminal branches. The *anterior* (*cochlear*) branch transmits to the brain auditory impressions from the organ of Corti. The *posterior* (*vestibular*) division of the eighth nerve is concerned with transmission of the sensations of equilibrium, which originate in the membranous semicircular canals and in other constituent elements of the membranous labyrinth. In its course through the internal auditory canal the eighth nerve may be injured by skull fracture, or it may be compressed from hyperostosis to the extent that the functions of both divisions are impaired. Within the cranial cavity the nerve or its sheath may be the point of origin for tumors arising at the cerebellopontine angle.

Surgical Considerations

Equilibrium depends not only upon impressions sent to the brain from the labyrinth, but also upon those sent from the eyes and from the muscles. If one set of impressions be destroyed, the resulting vertigo gradually is compensated for by the remaining two sets, which are sufficient to maintain balance properly. This compensation will not take place while infection in the labyrinth is active.

Sources of Labyrinthine Infection. Inflammation of the labyrinth is of mastoid, meningeal, tympanic or metastatic origin. The mastoid origin from erosion by cholesteatoma is by far the most common. The lateral semicircular canal is the commonest seat of localized labyrinthitis, since it is the one most immediately adjacent to the mastoid cells. Inflammation of the cochlea in its basal whorl may occur by infection through the oval window, following acute osteomyelitis of the stapes which fits into this window. A localized infection may spread to other portions of the perilymphatic space without involving the endolymph.

Infection may follow traumatic opening of the labyrinth in the course of a middle ear operation in which the stapes has been dislocated. This infection may complicate the removal of foreign bodies from the tympanic cavity, ill-performed paracentesis of the drum membrane, or radical mastoid operation in which the labyrinth at the level of the lateral or horizontal circular canal or the oval window is exposed to trauma.

Paths of Spread of Labyrinthine Infection. The labyrinth lies within the bony mass of the petrous pyramid with three connections between it and the posterior cranial fossa. The ductus cochlearis connects the perilymph space in the cochlea with the subarachnoid space near the jugular bulb. The endolymphatic (otic) sac lies in a split of the dura in the posterior cranial fossa posterior and lateral to the external auditory meatus. Infection of the labyrinth occurs more often by an abscess of the endolymphatic (otic) sac than by extension through the cochlear aqueduct. The third route of infection, which is the commonest of all, is along the fibers of the eighth nerve which extend from the cochlea and vestibule into the

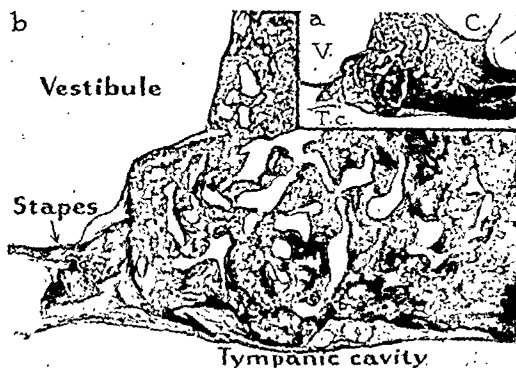
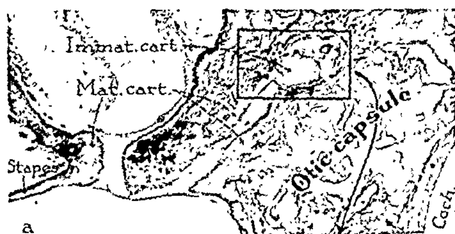

b
Vestibule
a
V.
C.
T.c.
Stapes
Tympanic cavity

Fig. 94


Immat.cart.
Mat.cart.
Stapes
Otic capsule
Coch.
a

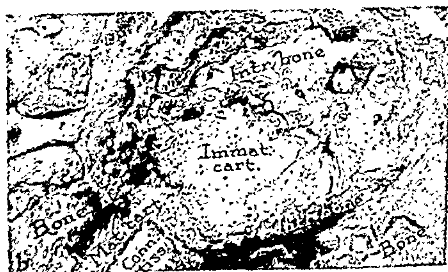

Intr. bone
Immat. cart.
Bone
Bone
b

Fig. 95

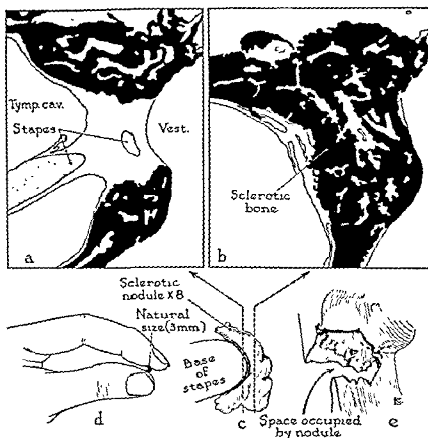


Fig. 96. DRAWINGS (VERTICAL SECTIONS) THROUGH THE SPONGIOUS BONE OF AN OTOSCLEROTIC NODULE AND DRAWINGS OF WAX-PLATE RECONSTRUCTIONS OF THE NODULE AND THE SURROUNDING AREA OF NORMAL BONE; FROM AN ADULT.

a, Section through the portion which borders upon the superior and inferior margins of the vestibular window at the anterior end of the latter (contiguous normal bone omitted). *b*, Section through a more anterior portion of the otosclerotic mass, just in front of the vestibular window (see levels indicated in *c*). × 26. *c*, Reconstruction of the nodule of otosclerotic bone shown as if enucleated from the normal bone (*e*) in which it was lodged, and as seen from the medial, or vestibular, aspect. *e*, Reconstruction of a portion of the capsule in which the nodule was situated, and from which the mass has been removed to leave an "excavation." × 8. *d*, The nodule, shown at natural size in relation to the size of the hand. × ½.

The sections demonstrate that the newly formed bone is vascular and porous and that it has completely replaced the normal osseous and cartilaginous tissues in the fenestral region; the figures of the reconstructions, enlarged, emphasize the latter feature and also demonstrate the way in which the pathologic tissue is imbedded in the normal; the figure of the nodule held by hand records the diminutive proportions of the area of sclerotic bone. (From Anson, Cauldwell and Bast: Ann. Otol., Rhinol. & Laryngol., 57: 103-28, 1948.)

Fig. 94. OTOSCLEROTIC BONE IN THE REGION OF THE FISSULA ANTE FENESTRAM, WITH RESULTANT ANKYLOSIS OF THE STAPES. ADULT SPECIMEN. PHOTOMICROGRAPHS OF SPECIMENS. *a*, × 13; *b*, × 34.

a, The otosclerotic nodule shown in relation to the vestibular fenestra (oval window) and to the cochlea. *b*, Details of histological structure.

Abbreviations: *C.*, cochlea; *T.c.*, tympanic cavity; *V.*, vestibule. (From Anson and Bast, in Coates: Otolaryngology, Hagerstown, Md., W. F. Prior Co.)

Fig. 95. PHOTOMICROGRAPHS (HORIZONTAL SECTIONS) OF THE VESTIBULAR ORIFICE OF THE FISSULA ANTE FENESTRAM AND A CARTILAGE NODULE (CHONDROMA) SITUATED NEAR THE COCHLEAR END OF THE FISSULA, IN AN INFANT 6 MONTHS OLD.

a, Includes the related cochlea, tympanic cavity, vestibule, and fissula ante fenestram. × 39. *b*, Records the difference between the normal cartilaginous shell and the pathologic tissue of the chondroma in the area indicated in *a*. × 180.

Abbreviations: *Coch.*, cochlea; *Conn. tiss.*, connective tissue; *Immat. cart.*, immature cartilage; *Intr. bone*, intrachondral bone; *Mat. cart.*, mature cartilage. (From Anson, Cauldwell and Bast: Ann. Otol., Rhinol. & Laryngol., 57: 103-28, 1948.

internal auditory meatus. This may result in a meningitis, or the infection may produce a cerebellar abscess.

OTOSCLEROSIS. The portion of the otic capsule of the internal ear, which is bounded by the cochlea, vestibule and tympanic cavity, is the most frequent site of occurrence of pathologic tissue in cases of otosclerosis (Figs. 94, 96). The area is crossed by a channel, the fissula ante fenestram, which, in certain respects, resembles the vestibular aqueduct. However, unlike the latter, the fissula does not transmit an epithelial duct; normally occupied merely by connective tissue, the fissula extends from the anterior wall of the vestibule (Fig. 95, *a*) to the tympanic cavity.

Small as is the fissula, the vestibular (oval) window is but little larger. As a consequence, any deforming effect which the exuberant production of otosclerotic bone may have on the

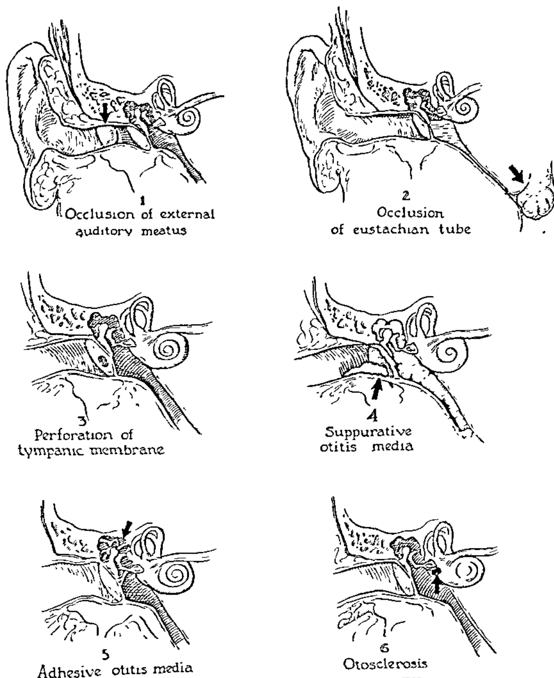


Fig. 97. SIX CAUSES OF CONDUCTION DEAFNESS.

Arrow points to the site of the obstruction or lesion. Of the several causative conditions, otosclerosis alone occurs within the otic capsule. (Courtesy of G. E. Shambaugh, Jr.)

fissular area will ultimately be exerted on the neighboring window. When newly formed bone, by encroachment on the fenestral space, reduces the excursion of the stapes, loss of hearing acuity occurs.

Commonly, especially in the young, the fissular tract is partially or wholly occupied by newly formed cartilage (Fig. 95, *a*, *b*). Frequently the cartilage undergoes slow and incomplete ossification in later life. In otosclerosis, on the contrary, the growth of the new vascular tissue is more rapid. The sclerotic bone tends to spread beyond the fissular area, and may form a part of the capsular wall in the region of the vestibular window, replacing the cartilage originally present there (Fig. 96). Further spread, with consequent encroachment on the space of the vestibular window, results in impingement on the stapes and in final ankylosis of the ossicle. The person then becomes aware of the insidious and painless onset of a slowly progressive impairment of hearing, as the mobility of the stapes is gradually reduced. Histologic otosclerosis which thus becomes clinically manifest through stapes fixation is referred to as clinical otosclerosis; it is the most important cause for progressive conduction deafness in adult life.

A frequent complication of clinical otosclerosis, with stapedial fixation, is degeneration of the auditory nerve, the cause of which, in the great majority of cases, remains unknown, and the occurrence of which bears no constant relation to ankylosis of the stapes in either its degree or time of onset. The fenestration operation for the first time permits positive confirmation in the living patient of a clinical diagnosis of otosclerosis by affording a direct view of the stapedial base and the otosclerotic focus through the operating microscope, by providing the opportunity of testing the mobility of the stapes, by palpation, and, in some cases, of removing a portion of the otosclerotic bone for biopsy. The diagnosis of clinical otosclerosis is made by first determining that the patient has a conduction type of

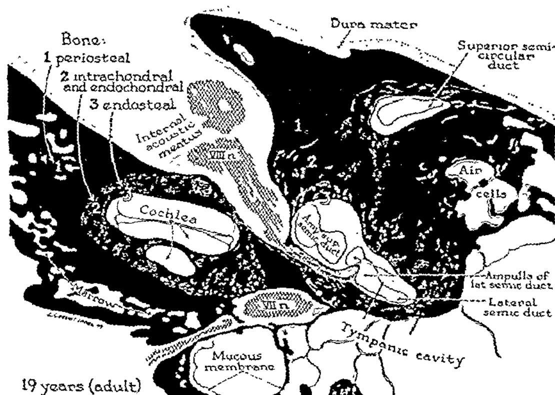
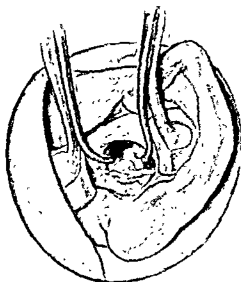
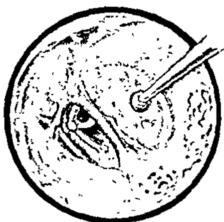


Fig. 98. SECTION OF THE OTIC CAPSULE IN A 19-YEAR-OLD ADULT. × 5. THE LAYERS OF THE OTIC CAPSULE ARE SHOWN.

The outer layer (at 1), besides enveloping the capsule, forms the bulk of the temporal bone. The inner layer (at 3) immediately invests the labyrinthic spaces. The middle layer (at 2), a combination of intrachondral and endochondral bone, is the crucial stratum in the technique of preventing closure of the artificial fenestra in endaural surgery. The opening is made into the lateral semicircular canal. (From Anson and Bast: Quart. Bull., Northwestern Univ. M. School, 23: 465-77, 1949.)



Insertion of irrigating attachment



Flattening of lateral aspect of bony horizontal semicircular canal



Bony canal enchondralization Grey line visible



Fracture of last layer of enchondral bone



Fenestra completed

Fig. 99. SUCCESSIVE STEPS IN THE FENESTRATION OPERATION.

(From Shambaugh: Acta Otolaryngol., Suppl., 79: 9–101, 1949.)

hearing impairment (by comparing the hearing by air with the hearing by bone); second, by excluding the other five causes for conduction deafness, namely, occlusion of the auditory meatus, perforation of the tympanic membrane, suppurative otitis media, secretory otitis media due to occlusion of the auditory (eustachian) tube, and adhesive otitis media due to a previous severe necrotic type of acute suppurative otitis media (Fig. 97).

In limiting the account of surgical correction to a discussion of the fundamental character of the otic capsule, and to means by which its regenerative behavior is put to use, it must first be pointed out that the histologic structure of the otic capsule is unique; it is composed of three layers of bone, namely, periosteal, endochondral (with contained intrachondral remnants) and endosteal (Fig. 98). The periosteal layer is relatively thick; its growth accounts for the early imbedding of the otic capsule; it forms the bulk of the adult temporal bone. The inner layer is always thin and fairly uniform in structure; it constitutes the immediate wall of the labyrinthine spaces. The middle layer is composed of islands of altered cartilage, which, as small islands in the course of fetal development, become surrounded by endochondral bone. The middle layer, in forming the bulk of the otic capsule, constitutes the petrous portion of the capsule. This intermediate stratum is a relatively inert

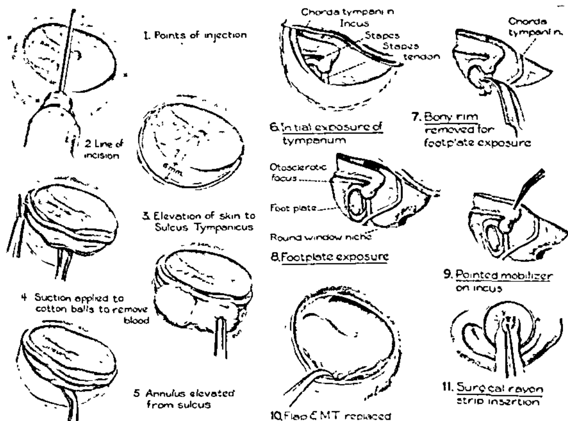


Fig. 100. PROGRESSIVE STEPS IN THE ENDAURAL OPERATION FOR MOBILIZATION OF THE STAPES, FIXED IN THE VESTIBULAR (OVAL) WINDOW BY THE PATHOLOGICAL GROWTH OF OTOSCLEROTIC BONE.

1, Points for injection of the anesthetic. 2, Position of length of the incision in the tympanic membrane. 3, Elevation of the skin lining the external acoustic meatus. 4, Removal, by suction, of the extravasated blood. 5, Elevation of the tympanic membrane from the sulcus in the tympanic ring. 6, Initial exposure of structures of the tympanic cavity (middle ear); the incus and chorda tympani are seen, as is also the cranial wall of the fossula of the cochlear fenestra (or niche of the round window). 7, Removal of bone internal to the tympanic sulcus exposes the base (footplate) of the stapes. 8, Wider exposure brings into view the facial canal and the tendon of the stapedial muscle. 9, Movement of a blunt mobilizer, applied to the incudostapedial joint, is calculated to fracture the otosclerotic bone and thus to free the stapes. 10 and 11, Replacement of the tympanic membrane, application of surgical gauze. ("Surgery of the Ear" by Dr. George E. Shambaugh, Jr.; textbook in preparation).

layer; upon this characteristic depends its special usefulness in the fenestration operation. When this layer is broadly exposed, then covered by a plastic skin flap, regeneration of the bone which bounds the artificial fenestra is prevented (Shambaugh).

After a thinned plastic skin flap has been made ready and an irrigating apparatus has been attached to the self-retaining retractor (Fig. 99, *upper*), a dental plug-finishing burr is applied to the lateral surface of the prominence of the bony, horizontal semicircular canal until a faint gray streak appears, denoting the lumen of the perilymph space shining through the thinned bone (Fig. 99, *middle left*). With the gray streak now in view as the site of the future fenestra, the burr is applied to remove periosteal bone until the ivory-like, slightly yellowish and coarsely granular endochondral layer of the horizontal and superior semicircular canals (Fig. 99, *middle left*) lies exposed in front of, above and posterior to the gray streak (Fig. 99, *middle right*). Having "enchondralized" the horizontal semicircular canal by exposing the osteogenically sluggish enchondral layer of the capsule widely in all directions, the actual fenestra is now made. The gray streak is widened and lengthened until the anterior end lies at the posterior extremity of the ampulla (compare Fig. 98). As the bone is thinned, the thin last layer of endosteal bone begins to fracture. Care is taken not to depress these fragments into the perilymph space, since the fractured area is enlarged to the desired size (Fig. 99, *lower left*). The endolymphatic horizontal semicircular canal now lies in full view, with the ballooning of the ampullated end anteriorly (Fig. 99, *lower right*). Finally, the plastic skin flap is placed over the fenestra and sutured with silk; the skin incision is closed surgically.

Recently a method has been developed for directly freeing the stapes from the otosclerotic nodule to which it has become ankylosed. This operation, termed stapes mobilization, is accomplished through the external auditory canal by first elevating the posterior half of the tympanic membrane so as to expose the stapes and its footplate. With adequate magnification the pattern of ankylosis may be determined, and with appropriate minute chisels and other instruments it may be possible to fracture through the ankylosis or to fracture the footplate adjacent to the area of ankylosis so as to restore the mobility of the stapes (Fig. 100).

CHAPTER 3

Regions about the Mouth

For anatomic and clinical consideration the regions about the mouth are divided into the labial, buccal, masseter-mandibular, zygomatico-pterygo-maxillary, and parotid. These regions, as well as those within the mouth, and the problems they present will be understood most clearly in the light of embryologic study.

The soft parts and the skeleton of the face are formed by the outgrowth of three buds, a median premaxillary and two lateral maxillo-mandibular (Fig. 101). Partial or total failure of one or more of these components to unite, form, and differentiate the nasal and buccal cavities gives rise to the various types of deformity about the nose and mouth.

The lateral buds grow toward the median line and divide to produce two processes, an inferior or mandibular, and a superior or maxillary. The mandibular processes unite in the midline to form the lower jaw, or mandible. Absence of union here is rare, but, when present, is manifested by a fissure of the lower lip.

The maxillary processes grow toward the midline to unite with the premaxillary bud or frontonasal process, which is a down-growth from the cranium. Union of these three processes forms the superior or maxillary arch. Defective union gives rise to a variety of anomalies. The premaxillary bud may unit with only one maxillary bud, producing a unilateral cleft on the side where fusion does not take place; it may unite with neither maxillary bud, and may extend downward and forward as a proboscis, in which case a bilateral cleft results. The deformity is designated as simple or complex, depending upon whether the lip alone is involved, or the hard and soft palates as well are affected. In the complex type the buccal and nasal cavities are in broad communication.

The maxillary processes form the zygomatic bones, the maxillae and the lateral parts of the lips. The descending median or premaxillary bud contributes to the formation of the nasal fossae and forms the incisor teeth and the intermaxillary portion of the upper lip and jaw.

The nasal areas presenting between the maxillary and premaxillary buds in the fourth week of embryonic life form the nasal pits, which, at this stage, are continuous with the mouth. They later become separated from it by union of the maxillary and premaxillary processes. The pits establish secondary connections with the roof of the early mouth cavity, and, by a thinning out and rupture of the bucconasal membranes, form the primitive choanae, or posterior nares. At a later stage the more cranial portion of the mouth cavity becomes a part of the nasal cavity by the formation, growth and fusion in the median plane of the paired palatal processes of the maxillary and palate bones. This constitutes the formation of the palate and the establishment of communication between the nasal cavity and the nasopharynx. The septum between the nasal pits narrows and becomes the nasal septum proper, dividing the nasal cavity into two paired nasal fossae.

In the eighth week of development the smooth lateral wall of each nasal fossa presents grooves or furrows which are the forerunners of the nasal meatuses. The furrows delimit folds which are the precursors of the nasal conchae, in which cartilage later develops. This cartilage, together with that of the septum and lateral nasal walls, largely undergoes ossification. The nasal mucous membrane evaginates into neighboring bones and leads to the formation of maxillary, sphenoid and frontal

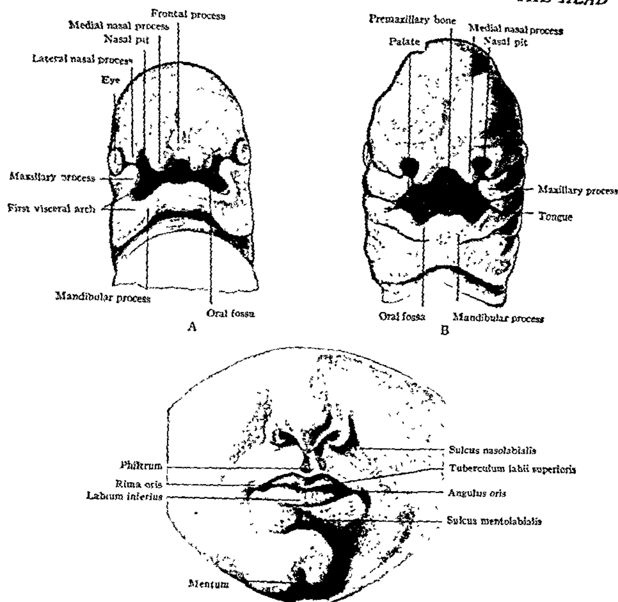


Fig. 101. EMBRYONIC AND ADULT FORM OF THE STRUCTURES ABOUT THE NOSE AND MOUTH.
Upper figures, Facial configuration, respectively in embryos of 8 mm. (19 days) and 14 mm. (35 days). *Lower figure*, Nasal and labial regions in the adult.

sinuses, and ethmoid cells. The initial points of evagination remain as the ostia of the adult sinuses and cells.

Labial (Lip) Region

DEFINITION, BOUNDARIES AND LANDMARKS. The lip region includes an upper and a lower fleshy fold which converge at lateral commissures, circumscribe the buccal orifice, and, when closed, form the anterior wall of the buccal cavity (Fig. 101). The upper lip is marked in the median line by the infranasal groove, which ends at the free border in a tubercle.

The human lip is traditionally described as having three zones, namely, cutaneous, glabrous and villous. Actually, in the living subject the so-called villous part bears no elevations. However, as soon as a fixing agent is applied, the *pars villosa* begins to assume a pebbly appearance (Fig. 102, *A*); the nodular character is due to the fact that the contracting epithelium is drawn into furrows around the tall dermal papillae (Fig. 102, *E*). When subjected to maceration, either artificial (Fig. 102, *B*) or natural (Fig. 102, *C*, *D*), free villi appear, as a result of loss of the epithelium which formerly overlay the papillae of the subjacent connective tissue.

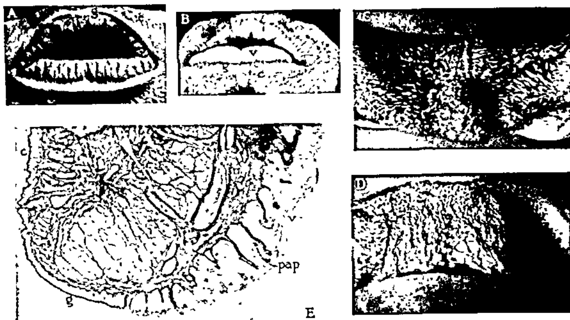


Fig. 102. ZONES OF THE HUMAN LIP SHOWN IN MACERATED SPECIMENS AND IN SECTION.

A, Outer aspect of the lips of a full-term fetus; formalin fixation about 3 hours post mortem; showing the typical labial zones. *B*, Similar view of the lips of a full-term fetus, after artificial maceration in Ringer's solution, showing especially a prominent villous zone. *C* and *D*, Inner surface of the upper and lower lips, respectively, of a stillborn fetus; natural maceration (intrauterine) by the amniotic fluid; demonstrating the tall denuded papillae of the villous zone. *E*, Vertical section of the upper lip of a newborn infant, showing the tall dermal papillae, which, in macerated specimens, appear as villous projections.

Abbreviations: *c*, cutaneous zone (*pars cutanea*); *g*, smooth zone (*pars glabra*); *pap.*, papillae of the dermal layer; *v*, villous zone (*pars villosa*).

(From Wherry and Anson: Am. J. Anat., 58: 73–85, 1936.)

DEEP STRUCTURES OF THE LIP. The essential muscle of the lip is the *orbicularis oris* (Fig. 103), which is disposed in an elliptical manner about the buccal aperture, the extremities of its upper and lower portions meeting at the lip commissures. To these commissures the bilateral facial muscles converge and are attached. These muscles, physiologically, are dilators of the orifice.

The orbicularis oris muscle closes the

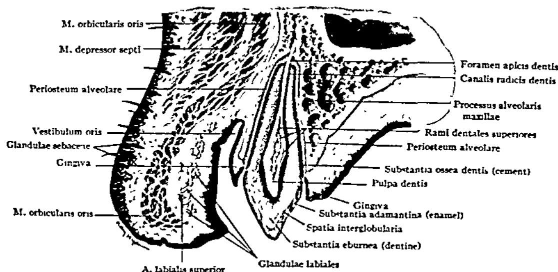


Fig. 103. SAGITTAL SECTION THROUGH THE UPPER LIP AND AN INCISOR TOOTH.

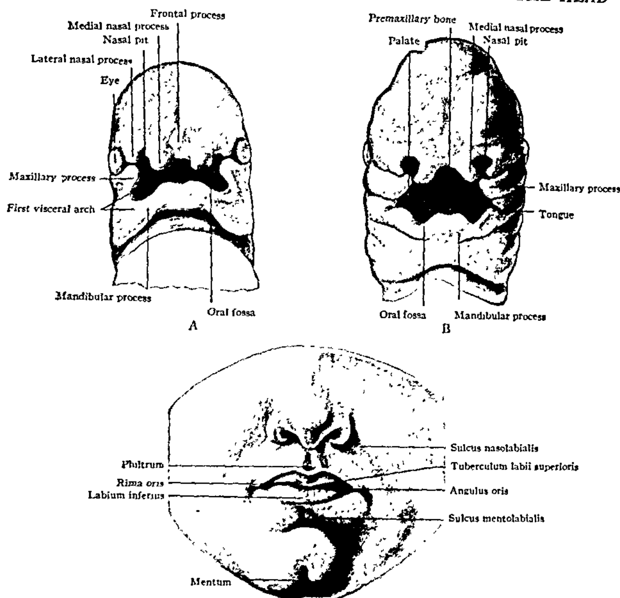


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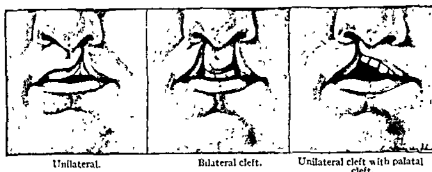


Fig. 104. TYPES OF HARELIP.

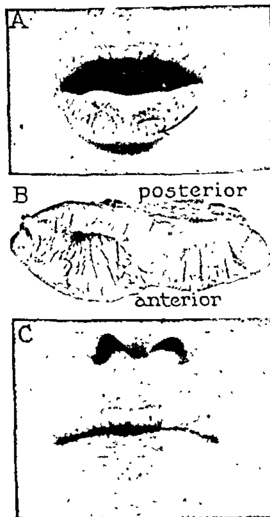


Fig. 105. LABIAL ANOMALY TERMED DOUBLE LIP.

A, Lips of a patient (male, 19 years of age) before operation. The upper lip is normal; the lower lip is coronally sulcate. Arrow points to the line of junction of the *pars glabra* (in front) and the *pars villosa* (behind). *B*, Excised piece. *C*, Lips of the same patient 3 months after operation. (From Mason, Anson and Beaton: Surg., Gynec. & Obst., 70: 12-17, 1940.)

embryonic elements which make up the lip and differentiate the nasal from the buccal cavity (Fig. 104). Harelip frequently is complicated by a corresponding cleft in the hard and soft palates. The degree of deformity may vary from a simple fissure to a complete cleft in the lip and in the alveolar portion of the palate (p. 97). In the repair of extensive clefts the importance of the frontonasal process must be recognized fully. Should it be removed, there would result a loss of the intermaxillary portion of the upper jaw and its central incisor teeth. This subject is continued on page 147.

DOUBLE LIP. One of the rarest of labial anomalies is the so-called double lip (congenital labial fistula, paramedian sulcus, sinus or pit). This type of congenital deformity occurs more commonly in females than in males, and is rarer in the upper lip than in the lower. In the case illustrated in Figure 105 the malformation consisted of coronally placed sulci, situated just within the vermilion border of the lip near the line of junction of the glabrous and villous zones (Fig. 105, *A*, at arrow).

Double lip is corrected surgically in the following way: the prolapsed area of mucous membrane and the glandular tissue in the submucosal layer are removed (Fig. 105, *B*); the mucous membrane of the posterior labial surface is then brought forward to the anterior edge of the incision, thereby obtaining an even suture line (Fig. 105, *C*).

Buccal (Cheek) Region

DEFINITION. The buccal region is the area between the inferior margin of the orbit and the lower jaw, extending from the anterior border of the masseter muscle to the fold of the nose and the commissure of the lip (Fig. 101).

STRUCTURES. The *fat* (*suctorial*) *pad* of the

mouth. It is supplied by the facial nerve, paralysis of which interferes with articulation, particularly that of the labial consonants, prevents tight closing of the mouth, and allows saliva to drip from the drooping corner.

The *glands* are labial, buccal or molar, according to their location, and are most numerous between the musculature and the mucosa. Tumors arising from these glands bulge through the mucous membrane.

VESSELS AND NERVES. A rich blood supply to the lips is afforded by the labial branches of the *external maxillary* (*facial*) *artery*, which have a coronary distribution deep to the orbicular muscle and are therefore nearer to the mucous membrane than to the skin. The labial arteries are large, and their pulsation sometimes can be felt. In trauma of the lips against the teeth, the lips may be cut and free bleeding result. The *veins* lie to the outer side of the muscle. The *lymphatics* are arranged in plexuses lying within the mucous membrane and skin; they follow the facial vein and empty into the submaxillary nodes. Those originating in the median portion of the lower lip drain into the submental glands, while those in the lateral portions drain directly into the submaxillary glands (Fig. 3, p. 6).

Certain channels decussate and empty into the glands of the opposite side. The lymphatic drainage in and about the lips has great surgical significance because of its role in carcinoma of the lip. Metastatic involvement continues from the submental and submaxillary nodes to the superior and inferior chains of the deep cervical nodes.

Surgical Considerations

Because the lips have no bony attachments, the healing of a severe injury or of a destructive infection, with consequent contracture of muscle and scar tissue, is likely to result in mouth deformity and even serious distortion of neighboring structures. The great vascularity of the lips and their freedom from bony attachment partly account for the success of the many plastic operations devised for the relief of deformities.

CARCINOMA OF THE LIP. Carcinomas of the lip most commonly involve the lower lip, and the lesion there is almost always of the squamous cell type. Overexposure to sunshine over a long period of years is frequent in the history of these patients, who are often outdoor workers such as farmers, road workers, and the like. Chronic irritation from pipe smoking has also been long recognized as an etiologic factor, probably related to tobacco tar contact.

The early change is often a fissure, chronic leukoplakic area or flat ulcer which finally becomes malignant. All lesions which fail to heal in four weeks should be viewed with suspicion and biopsied by small section excision or complete excision if the abnormality is small. If positive for carcinoma, plans are made for a more radical excision or treatment with some form of radiation therapy. The latter, properly applied, is highly effective in eradicating the primary lesion with relatively little deformity.

Concerning the treatment of regional lymph nodes possibly involved with metastases from the lip, there is considerable difference of opinion. Certainly if cervical lymph nodes are enlarged, a bilateral supraomohyoid neck gland dissection (Figs. 161, 200) should be done immediately, or as soon as it can be determined that the local lesion can be controlled. Without enlarged regional lymph nodes, excellent authorities disagree. Some advise against a "prophylactic dissection" on the basis that, according to statistics, approximately 80 per cent of patients with carcinoma of the lip do not have neck metastases, and in a large series at Memorial Hospital, New York, it was found that in those admitted without palpable evidence of cervical metastases and in whom the primary lesion was cured, only 8 per cent subsequently had metastases during an observation period of five years. On the other hand, while the presence or absence of enlarged nodes is the best guide for the presence of metastases, and therefore the need for immediate neck dissection, there are many errors either way. Taylor* found 8 per cent of his patients without palpable nodes to have microscopic metastases; 9 per cent of nodes less than 1 cm. in diameter were positive, as were 67 per cent of those between 1 and 2 cm., and 91 per cent of those over 2 cm. He also noted that 27 per cent of the patients thought to have clinically negative necks were positive, while 36 per cent of the patients thought to have metastases on clinical examination were found to be negative on microscopic examination of the neck specimens.

HARELIP. The common congenital deformity of harelip results from the nonfusion of the

* Radiology, 55: 60, 1950.

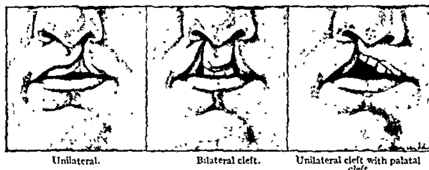


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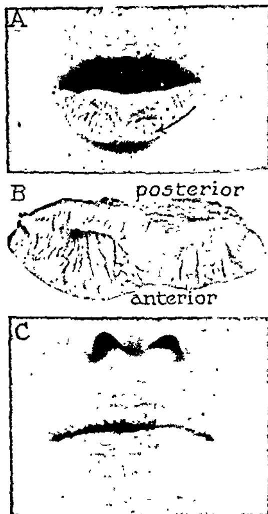


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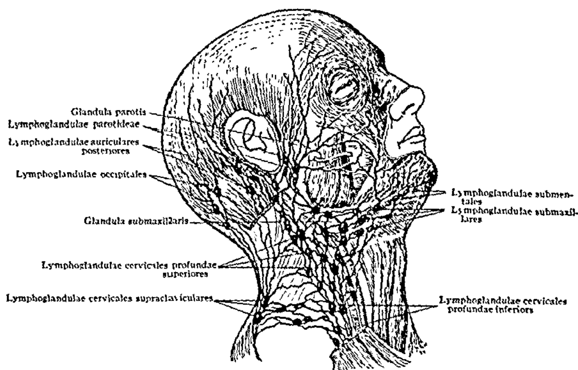


Fig. 108. LYMPH DRAINAGE TO THE SUBMAXILLARY AND DEEP CERVICAL LYMPH NODES.

attached to the skin and orbicularis oris muscle, thereby controlling facial expression. For the most part, they converge to the labial commissures. Extending from the alveolar arch of the maxilla to that of the mandible is the more deeply placed buccinator muscle, which forms the lateral wall of the mouth.

The *parotid duct* (of Stensen), after passing forward from the surface of the masseter muscle, perforates the buccinator muscle obliquely, and courses anteriorly on the buccal mucous membrane (Figs. 106, 107). Its course is represented by the middle third of a line drawn from the inferior edge of the external acoustic meatus to a point midway between the ala of the nose and the commissure of the lip. It penetrates the buccal mucosa, and opens into the vestibule of the mouth by a slitlike orifice on a variably developed papilla opposite the second upper molar tooth; through this orifice the duct may be catheterized. The duct furnishes a path for infection from the mouth to the parotid gland. When the duct is severed, its proximal end may grow fast to the skin surface, forming a fistula which is difficult to heal. To repair this condition, the cut ends of the duct should be approximated by sutures which do not enter the lumen of the duct.

The *external maxillary* (*facial*) *artery*, the only important artery to the cheek, enters the antero-inferior angle of the masseter mu cle, courses forward on the buccinator muscl and becomes the angular artery at the corn of the mouth (Fig. 106). It is accompanied the anterior facial *vein*, which, at its origin, h direct communication with the ophthalm veins and, through them, with the cavernou sinus. Infections in this region, particularly c the upper lip and nose which may result i facial phlebitis, are exceedingly grave, sinc they may be propagated by this direct route t the cavernous sinus and cerebral meninge (Fig. 17, p. 18).

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Masseter-Mandibular-Temporal Region

The masseter-mandibular-temporal regio is the pivotal region in which the mandible, th only movable bone of the face, is controlled i its relations with the superior maxilla at th temporomandibular joint. Within the area ar the ramus and body of the mandible, the over lying masseter muscle, its fascia, a portion o the parotid gland and duct, the dense paroti

cheek is a collection of the fat of the subcutaneous tissue in the space between the buccinator and masseter muscles. This fatty tissue is continuous with that of the temporal and deep lateral regions of the face, and explains the ready spread of infection or carcinoma to these regions.

The superficial muscle layer is made up of many small *muscles* adjacent to the mouth; these have the common characteristic of being

Fig. 106. STRUCTURES ON THE SIDE OF THE FACE.

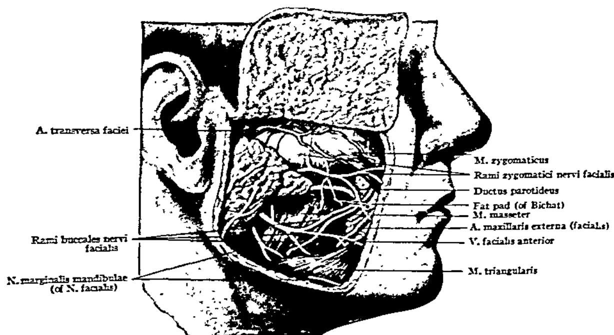


Fig. 107. SUPERFICIAL STRUCTURES OF THE MASSETER REGION AND PART OF THE CHEEK.

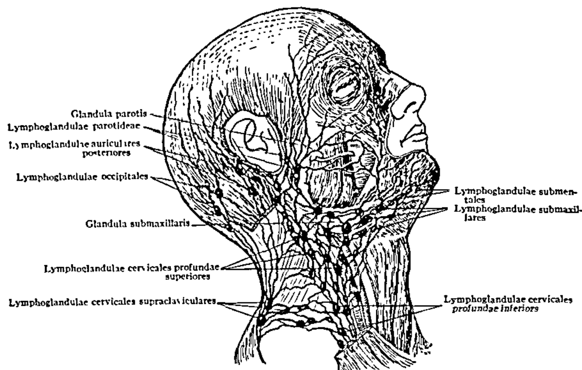


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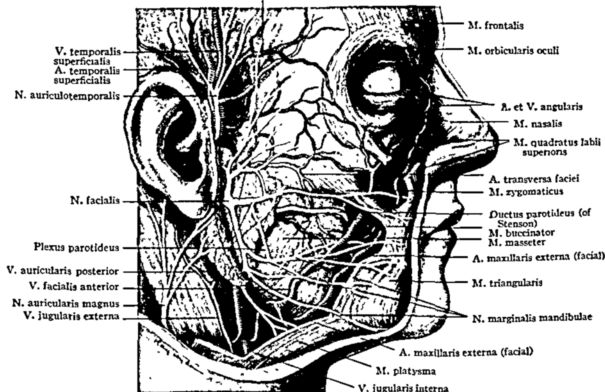


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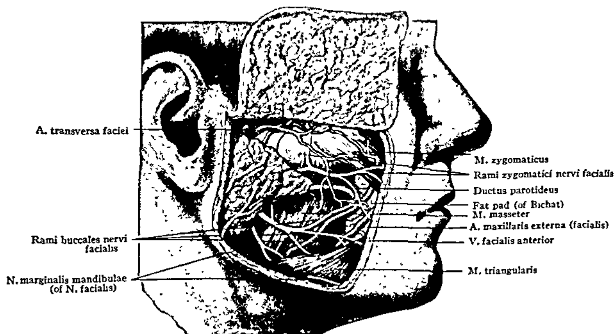


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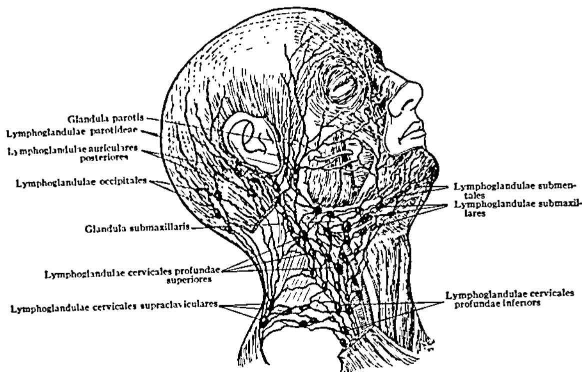


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attached to the skin and orbicularis oris muscle, thereby controlling facial expression. For the most part, they converge to the labial commissures. Extending from the alveolar arch of the maxilla to that of the mandible is the more deeply placed buccinator muscle, which forms the lateral wall of the mouth.

The *parotid duct* (of Stensen), after passing forward from the surface of the masseter muscle, perforates the buccinator muscle obliquely, and courses anteriorly on the buccal mucous membrane (Figs. 106, 107). Its course is represented by the middle third of a line drawn from the inferior edge of the external acoustic meatus to a point midway between the ala of the nose and the commissure of the lip. It penetrates the buccal mucosa, and opens into the vestibule of the mouth by a slitlike orifice on a variably developed papilla opposite the second upper molar tooth; through this orifice the duct may be catheterized. The duct furnishes a path for infection from the mouth to the parotid gland. When the duct is severed, its proximal end may grow fast to the skin surface, forming a fistula which is difficult to heal. To repair this condition, the cut ends of the duct should be approximated by sutures which do not enter the lumen of the duct.

The *external maxillary* (*facial*) *artery*, the only important artery to the cheek, enters at the antero-inferior angle of the masseter muscle, courses forward on the buccinator muscle, and becomes the angular artery at the corner of the mouth (Fig. 106). It is accompanied by the anterior facial *vein*, which, at its origin, has direct communication with the ophthalmic veins and, through them, with the cavernous sinus. Infections in this region, particularly of the upper lip and nose which may result in facial phlebitis, are exceedingly grave, since they may be propagated by this direct route to the cavernous sinus and cerebral meninges (Fig. 17, p. 18).

The *lymph drainage* is to the submaxillary and deep cervical lymph nodes (Fig. 108). The muscles of the cheek are innervated by the facial *nerve* (Figs. 106, 107, 109 to 111).

Masseter-Mandibular-Temporal Region

The masseter-mandibular-temporal region is the pivotal region in which the mandible, the only movable bone of the face, is controlled in its relations with the superior maxilla at the temporomandibular joint. Within the area are the ramus and body of the mandible, the overlying masseter muscle, its fascia, a portion of the parotid gland and duct, the dense parotid

fascia, and the vessels and nerves coursing anteriorly over the masseter muscle.

LANDMARKS. At the antero-inferior border of the region the external maxillary (facial) artery winds about the body of the mandible, where it can be palpated and its pulsations felt (Fig. 106). By clenching the jaws tightly, the thickness of the masseter muscle over the angle of the jaw may be brought into prominence.

SUPERFICIAL STRUCTURES. The bulk of the *parotid gland* lies on the side of the face posterior to the angle of the jaw (p. 130), but its anterior facial prolongation and duct are superficial structures within this region (Figs. 106, 107). From the deep cervical fascia is derived the *parotid fascia*, which divides to embrace the gland (see Parotid Region, pp. 129 to 141). The fascia over the anterior prolongation of the parotid blends with the fascia on the masseter muscle. The *parotid duct* emerges through the masseter fascia, winds around the anterior border of the masseter muscle, and enters the buccinator muscle in the cheek region (p. 135). In their course to the anterior regions of the face the *transverse facial artery* and the zygomatic and buccal branches of the *facial nerve* traverse this region. Vertical incisions, therefore, are ill advised, since they sever these structures. An incision from the tragus of the ear to the commissure of the lip uncovers the duct in its course over the masseter. Injury to the duct where it lies on the masseter muscle may result in a salivary fistula, which is difficult to cure.

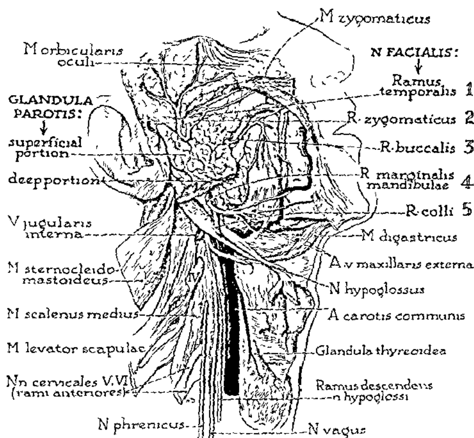


Fig. 109. FACIAL NERVE AND PAROTID GLAND.

The superficial lobe of the parotid gland has been restored to its normal position, the lower portion cut away in order to demonstrate the relation of the facial nerve to the cleavage plane which intervenes between the superficial and deep lobes. In the region cranial to the zygomatic arch, fatty tissue has been dissected along the course of the temporal rami of the nerve, in order to make clear the depth at which the nerve branches course in the superficial fascia. The parotid duct is marked by *. In addition to the temporal rami sent dorsalward to the auricular muscles and ventralward to the muscles of the eyelid, rami pass cranialward to the frontalis portion of the epicranius. Zygomatic branches supply the inferior portion of the orbicularis oculi as well as the zygomaticus. The latter muscle, together with the musculature of the nose and mouth, receives supply from the buccal rami. The marginal mandibular branch sends twigs to the quadratus labii inferioris and to the mentalis. The cervical ramus, covered by the platysma, supplies that muscle. (From Davis, Anson, Budinger and Kurth: Surg., Gynec. & Obst., 102: 385-412, 1956.)

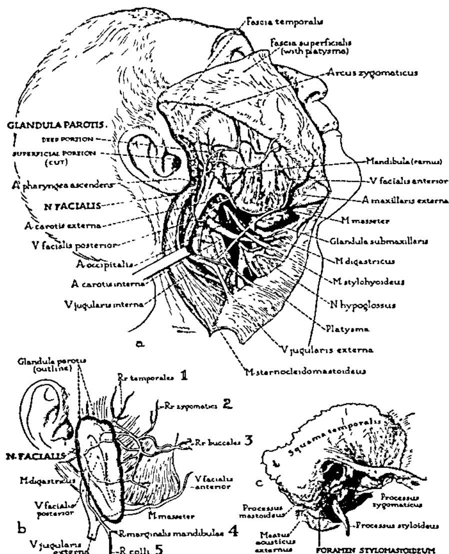


Fig. 110. PAROTID GLAND AND FACIAL NERVE, TOGETHER WITH THE VASCULAR, NEURAL, MUSCULAR AND SKELETAL STRUCTURES RELATED TO EACH.

a, Structures revealed by reflection of the superficial fascia (with its contained platysma), by retraction of the sternocleidomastoid muscle and posterior facial vein and by excision of the superficial leaf of the parotid gland. The facial nerve emerges from the space between the deep and superficial leaves of the gland (the latter portion cut away). The vagus nerve is indicated by the arrow. *b*, Facial nerve (same specimen) in relation to the masseter muscle, to the superficial leaf of the parotid gland (outlined) and to the facial tributaries of the external jugular vein. *c*, Temporal bone, recording in lateral view the relation of the stylomastoid foramen to the mastoid process, the external acoustic meatus, the styloid process, and the sheath of the latter prominence. (From Davis, Anson, Budinger and Kurth: Surg., Gynec. & Obst., 102: 385-412, 1956.)

The parotid gland is variable in form and size (Figs. 109, 110, 124, 127, 128). The deep lobe may be merely a small button of glandular tissue, or may come close to equaling in size its overlying superficial lobe.

The facial nerve, lying between the two lobes of the parotid gland, partially separates the gland into a large superficial and a small deep portion (Figs. 109 to 111); the two parts are connected by an isthmus which passes between the diverging portions of the nerve. With the exception of one or two small muscular rami, all the branches arise after the nerve has reached the gland (Figs. 106, 107).

The *masseter fascia* binds the underlying muscle to the margin of the ramus and the body of the mandible. An expansion of this fascia overlies and secures the fat pad of the cheek to the buccinator muscle (p. 115). The parotid duct lies within the fascia and, in a measure, is protected by it.

MASSETER MUSCLE. The masseter muscle

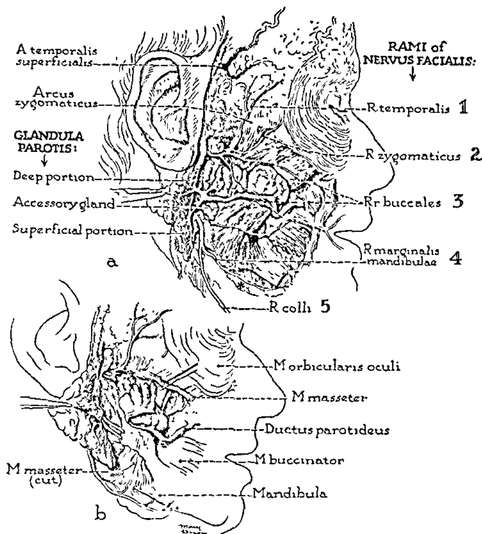


Fig. 111. FACIAL NERVE, PAROTID GLAND AND DUCT.

a, Temporofacial and cervicofacial divisions of the facial nerve, the 5 regular branches of the latter, the 2-layered parotid gland, and the extraglandular "ductules" tributary to the parotid duct. The superficial portion of the gland, here reflected, covered its deep portion (but not the accessory part), the tributaries of the main duct, and the roots of division of the nerve. The mandibular ramus of the facial nerve crossed the submaxillary gland (at *). *b*, Anterior part of the superficial leaf of the parotid gland reflected (after cutting the duct) with resultant exposure of the deep portion. The latter occupies the parotid fossa in the area behind the ramus of the mandible. The masseter muscle has been partially excised in order to demonstrate the relation of the gland to the mandible. The temporofacial and cervicofacial divisions of the nerves have been cut (at arrows) near the point where they pass cranial and caudal, respectively, to the isthmus of the gland. (From Davis, Anson, Budinger and Kurth: Surg., Gynec. & Obst., 102: 385–412, 1956).

runs from the zygomatic arch to the angle of the mandible and covers the lateral surface of the ramus (Fig. 112). In tetanus it goes into contracture early. Inflammatory lesions about the mandibular joint may produce a chronic masseter myositis with subsequent fibrosis, which may restrict the play of the muscle and limit movement of the jaws.

Temporal Muscle and Fascia. The broad radiating temporal muscle arises from the temporal fossa and the temporal fascia. Its fibers converge into a tendon which passes deep to the zygomatic arch and inserts into the coronoid process of the mandible. The temporal fascia covers the temporal muscle and is attached below to the zygomatic arch.

Skeletal Framework. The framework is the zygomatic process and the mandibular fossa of the temporal bone, and the ramus and angle of the mandible (Fig. 112). A most important landmark in cranio-encephalic topography is the zygomatic arch, formed from the horizontal processes of the malar and temporal bones. On the upper margin of the ramus of the mandible are two processes, the coronoid and the condyloid. The coronoid process is the

upward continuation of the anterior border of the ramus of the mandible; it affords insertion mainly to the temporal muscle. The condyloid process is the upward continuation of the posterior border of the ramus.

TEMPOROMANDIBULAR JOINT. The temporomandibular joint is compound, with its socket in the temporal bone and its condyle surmounting the ramus of the mandible (Figs. 112, 113). Within the joint is an interarticular disk which divides the joint cavity into upper and lower divisions. The posterior wall of the temporal glenoid fossa is the anterior wall of the external auditory meatus, a fact which explains how trauma to the chin may thrust the condyle far enough upward and backward to injure the meatus and even penetrate its cavity (p. 80). Since only a thin bony plate separates the temporal glenoid fossa from the brain, a suppurative joint lesion may invade the intervening bone and result in subdural abscess or meningitis.

The strong lateral or temporomandibular ligament protects the joint laterally. The reinforced capsule is sufficiently strong to maintain the articular contents in apposition without the

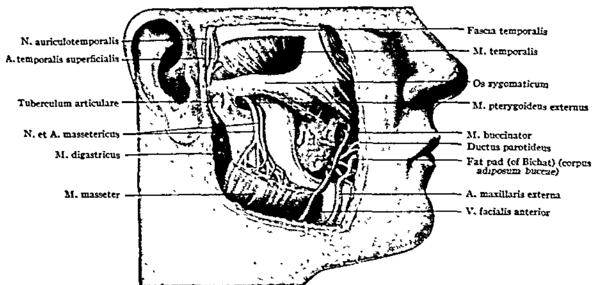


Fig. 112. DEEP STRUCTURES OF THE MASSETER REGION.

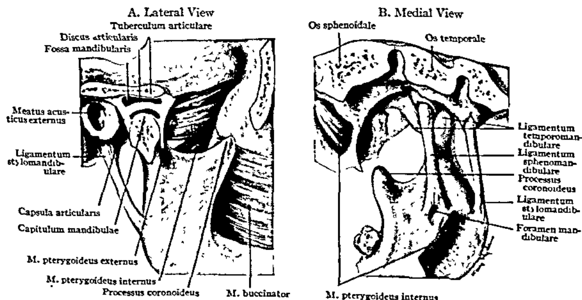


Fig. 113. LATERAL AND MEDIAL VIEWS OF THE REGION ABOUT THE TEMPOROMANDIBULAR JOINT.

Fig. 114. MASTICATOR SPACE.
The mandible has been removed. (From Coller and Yglesias: Surg., Gynec. & Obst., 60: 277–90, 1935.)

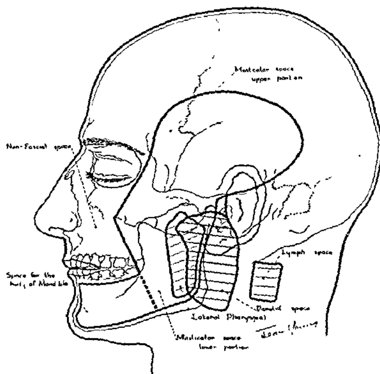


Fig. 115. SURFACE PROJECTION OF MASTICATOR AND RELATED SPACES.
(From Coller and Yglesias: Surg., Gynec. & Obst., 60: 277–90, 1935.)

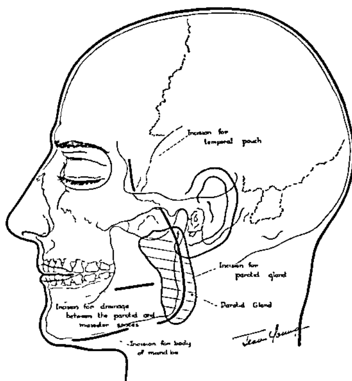


Fig. 116. DRAINAGE INCISIONS FOR FACIAL SPACES.
(From Coller and Yglesias: Surg., Gynec. & Obst., 60: 277–90, 1935.)

aid of accessory ligaments. The external pterygoid muscle is a powerful reinforcement to the joint. It arises from the base of the skull, runs horizontally backward, and inserts into the neck of the condyle of the mandible and into the disk and capsule of the joint.

MASSETER-MANDIBULOPTERYGOID (MASTICATOR) SPACE AND PROLONGATIONS. Coller and Yglesias called attention to a space occupied by the masseter muscle, the ramus, and posterior part of the body of the mandible and the pterygoid muscles (Figs. 114, 115). This space extends superiorly to the level of the insertion of the temporal muscle. It is difficult for enclosed infection here to spread inferiorly, superficially or medially. It can pass upward, however, into the temporal prolongations of this space, areas superficial and deep to the temporal muscle insertion on the coronoid process (temporal pouches).

Abscess within the space may point at the anterior border of the masseter muscle or internally into the mouth. These sites may be used for drainage (Fig. 116). Infection may point posteriorly deep to the parotid gland, simulating a deep parotid abscess. Osteomyelitis of the zygomatic arch involves the superficial temporal pouch. Infection of the squama of the temporal bone invades the deep pouch.

The temporal spaces can be drained by a vertical incision posterior to the lateral rim of the orbit, developed through the temporal fascia.

Surgical Considerations

DISLOCATION OF THE MANDIBLE, AND ITS REDUCTION. The mandibular joints are strengthened by muscle and ligament supports so that they permit anterior dislocation only (Fig. 117). Dislocation ordinarily occurs when the mouth is wide open and the condyles and the interarticular disks are forward on the upper joint eminences. With the jaws in this position, a spasmodic muscle effort or a downward blow on the chin throws the condyles forward out of their sockets. After dislocation the combined contraction of the temporal, masseter and pterygoid muscles holds the condyles in this forward position and wedges the coronoid processes firmly in the zygomatic fossae.

To reduce this dislocation, the condyles must be depressed and pushed back to their proper articular surfaces. The padded thumbs are placed against the last molar teeth, and,

Temporal fascia
Masseter muscle and fascia
Temporal muscle
Zygomatic process
Int maxillary arter
Ext pterygoid muscle
Neck of mandible
Superficial temporal artery
Int pterygoid muscle
Styloid process
Ext carotid
Lingual nerve
Pterygoid fascia
Inf alveolar nerve

Fig. 114. *MASTICATOR SPACE.*

The mandible has been removed. (From Coller and Yglesias: Surg., Gynec. & Obst., 60: 277–90, 1935.)

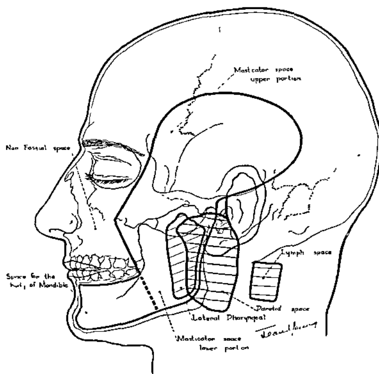


Fig. 115. *SURFACE PROJECTION OF MASTICATOR AND RELATED SPACES.*
(From Coller and Yglesias: Surg., Gynec. & Obst., 60: 277–90, 1935.)

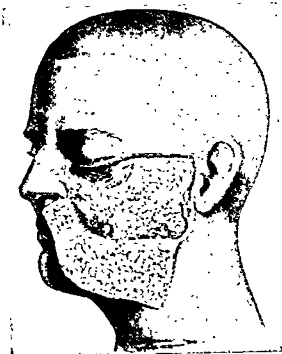


Fig. 118. EXTRAORAL APPROACH TO LARGE OR MULTIPLE LESIONS OF THE CHEEK.

The incision is begun just lateral to the alar wing of the nose. It then extends superiorly along the nasofacial crease to a point approximately 2 cm. below the inner canthus. It is then carried laterally along the junction of the lower lid and skin of the maxillary area to a point just lateral to the outer canthus. The excision is then extended across the zygomatic area to the ear and thence along the auriculofacial junction to the angle of the mandible. The area of skin thus outlined is elevated from the underlying tissues and turned down to expose the entire substance of the cheek. If additional exposure is needed, the incision can be extended under the mandible to the external maxillary vessels and along the nasolabial groove to the commissure of the mouth. (From Maguire, Horton and Pickrell: Arch. Surg. 71: 896–906, 1955.)

masses in the cheek several factors must be taken into account. The incision must be planned to avoid an offensive scar. For a large exposure, one placed along the nasofacial groove, the infraorbital area and the auriculofacial junction seem to produce the least deformity (Fig. 118). Only the skin and subcutaneous tissue should be reflected. If deep dissection is necessary, adjacent branches of the facial nerve (Figs. 106, 107, 110) and the parotid duct (Figs. 106, 107, 109) should be exposed for preservation.

Zygomatico-pterygomaxillary (Deep Lateral) Region of the Face

DEFINITION, BOUNDARIES AND LANDMARKS. The zygomatico-pterygomaxillary region lies deep to the masseter-mandibular region, and extends from the parotid gland forward to the cheek (Fig. 119). It offers surgical approach to the trigeminal nerve and its semilunar and sphenopalatine ganglia. Accurate diagnosis of facial neuralgia calls for an intimate knowledge of the trigeminal nerve distribution. Severe neuralgia requires severing the sensory roots. The peripharyngeal space alone separates the region from the pharynx. Clinical examination and operation in this region are hindered by the overlying masseter muscle and mandible, but a limited exploration can be made through the mouth and pharynx.

WALLS OF THE SPACE. The *lateral wall* of this irregular and ill-defined space is the medial surface of the ramus of the mandible. The only outward communication with the masseter compartment is through the notch in the superior border of the ramus between the coronoid and condyloid processes. The bony portion of its *superior wall* is composed of parts of the great wing of the sphenoid and the temporal bone. The remainder of the superior wall is occupied by the large opening between the zygomatic arch and the skull. Through this wide space the region is in communication with the temporal region. The *anterior wall* above is the tuberosity of the maxilla; below it are the bulging fibers of the buccinator muscle and part of the superior constrictor muscle of the pharynx. The bony elements of the *medial wall* form the zygomatic and pterygomaxillary fossae, within which lie the two pterygoid muscles, the interpterygoid fascia, the internal maxillary vessels and the maxillary and mandibular nerves.

MUSCLES. The *internal pterygoid muscle* arises from the walls of the pterygomaxillary fossa, and is directed downward, outward and backward to the angle of the jaw. As a levator of the jaw, it is almost as powerful as the masseter muscle. The dense *interpterygoid fascia,* fixed above to the base of the skull, covers the lateral surface of the internal pterygoid muscle and is attached to the ramus and angle of the jaw. The inferior alveolar and lingual vessels and nerves course over its lower lateral surface. The *external pterygoid muscle* arises from the walls of the zygomatic and pterygomaxillary fossae and inserts mainly into the neck of the mandible (Fig. 119). Its action is to draw the jaw forward.

VESSELS AND NERVES. The chief vessel of the deep portion of the face is the *internal maxillary*

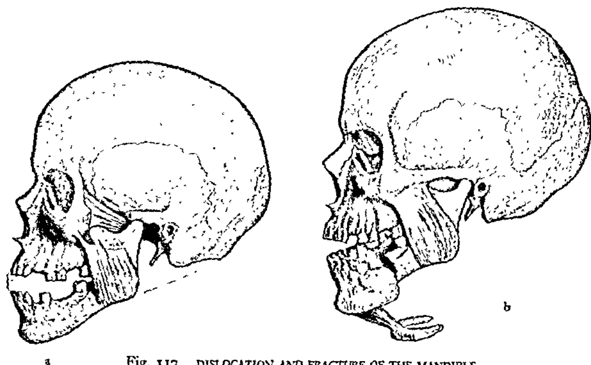


Fig. 117. DISLOCATION AND FRACTURE OF THE MANDIBLE.

a, Anterior dislocation of the mandible, showing the action of the external pterygoid and masseter muscles in fixing the deformity. *b*, Fracture of the mandible anterior to the masseter muscle. The proximal fragment is displaced upward by the masseter and temporal muscles; the anterior fragment is displaced downward and backward by the geniohyoid, genioglossus, anterior part of the mylohyoid, digastric and platysma muscles. (From Babcock: Textbook of Surgery.)

with the fingers about the jaws, pressure is exerted downward and backward on the jaw until the condyles are loosened and lowered. The jaws then can be closed over the thumbs by pulling up the chin; the thumbs are used as levers. If manual reduction fails, a wedge may be placed between the upper and lower molars and the chin pressed upward and forward.

FRACTURE OF THE MANDIBLE. Fracture of the mandible usually occurs in the body of the bone near the canine tooth, or a little lateral to the symphysis (Fig. 117). It generally is compound into the mouth because the alveolar periosteum and buccal mucous membrane are torn at the line of fracture. The posterior fragment tends to override the anterior fragment. If the fracture is anterior to the masseter muscle, any deformity present is shown by malalignment of the teeth. The anterior (distal) fragment is drawn downward and backward by the action of the geniohyoid, digastric and genioglossus muscles. The temporal, internal pterygoid and masseter muscles draw the overriding posterior (proximal) fragment upward and forward.

Unless early immobilization of the fracture is effected, infection from the compounding into the mouth involves the submaxillary and deep cervical lymph nodes. Osteomyelitis of the jaw also may result. The deformity must be corrected carefully and the teeth be brought into perfect alignment. To secure and maintain apposition, it is necessary to wire the teeth or fragments together or to apply an interdental splint.

APPROACH TO LARGE OR MULTIPLE LESIONS OF THE CHEEK. Lesions involving the skin or mucous membrane of the cheek are removed by a direct approach through the surface covering most affected. After removal of small lesions closure can ordinarily be done by simply approximating the wound edges. Large defects may require some sort of flap closure, the simple sliding type offering the easiest repair.

Subsurface lesions offer the choice of an intraoral or extraoral approach. The decision is dependent largely upon whether a malignancy is expected and radical excision a possibility. Masses lying superficial to the buccinator fascia cannot be removed by the transoral route without danger of poor exposure and possible damage to the facial nerve. Masses deep to the buccinator fascia are best removed through a mucous membrane incision, care being taken to preserve the parotid duct.

In the extraoral approach to large or multiple

Fascia temporalis
M. temporalis
Vv. articulares mandibulae
A. et N. massetericus
A. et V. temporalis media
A. et V. temporalis superficialis
A. zygomaticus
A. meningea media
A. maxillaris interna
A. auricularis posterior
V. facialis posterior
A. carotis externa
A. occipitalis
M. pterygoideus internus
N. lingualis
A. et N. massetericus
M. masseter
N., A. et V. alveolaris inferior
V. jugularis interna
V. facialis communis
Nn. temporales profundi
A. temporalis profunda superior
Os zygomaticum
A. alveolaris superior posterior
Plexus venosus pterygoideus
Ramus profundus V. facialis anterioris
A. et N. buccinatoria
M. buccinator
A. maxillaris externa
V. facialis anterior
V. facialis anterior
A. maxillaris externa

Fig. 120. STRUCTURES IN THE DEEP LATERAL REGION OF THE FACE.

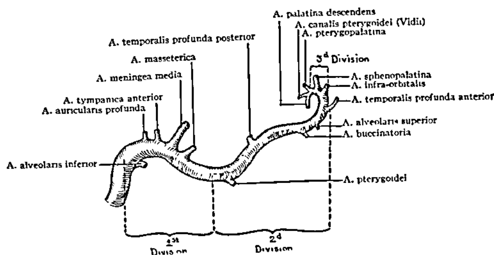


Fig. 121. DIVISIONS AND BRANCHES OF THE INTERNAL MAXILLARY ARTERY.

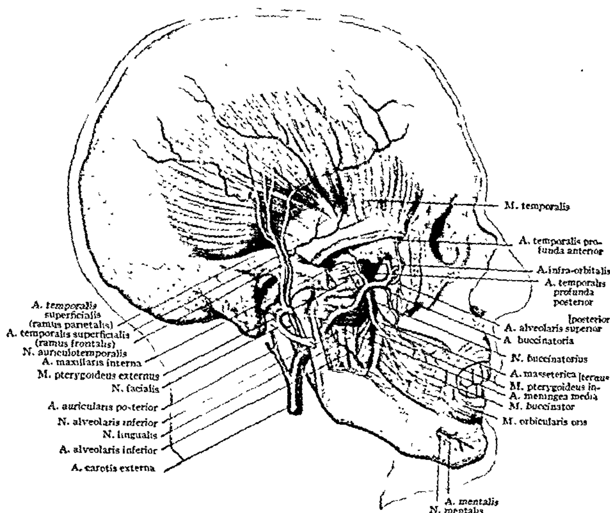


Fig. 119. DEEP STRUCTURES IN THE ZYGOMATICO-PTERYGOMAXILLARY REGION.

artery, a branch of the external carotid (Figs. 120, 121). The artery runs forward and medialward from the neck of the mandible. Continuing tortuously, but in generally ascending course, the artery lies between the temporal and external pterygoid muscles; it sends local rami to these muscles, to the adjacent masseter and to the neighboring muscles of facial expression. Many small, yet important, branches leave the zygomaticotemporal region to enter foramina in the base of the skull, the mandible and the maxilla. These rami supply the cranial meninges, the external and the middle ear, the teeth and gums, the bones of the jaw and the contents of the orbit.

The *trigeminal nerve* is widely distributed on the face and scalp (Fig. 122).

The branches of the *ophthalmic division* reach the face by passing through the orbit. The lacrimal nerve emerges from the orbit to supply the skin at the lateral angle of the eye. The supraorbital nerve, passing through an incisura (in some instances a fissure) of the same name, supplies the skin of the forehead as far back as the vertex. The supratrochlear nerve, named for its relation to the trochlea of the superior oblique muscle, courses forward on the medial wall of the orbit; emerging, its rami care for the innervation of the skin at the root of the nose, of the upper eyelid and of the forehead. The infratrochlear nerve sends its cutaneous rami to the caruncula, both lids and the nose. In addition to the branches illustrated, the external nasal ramus of the anterior ethmoidal nerve also contributes to the innervation of the nose; it attains a superficial position by emerging from the nasal bone and cartilage.

The *maxillary division* of the trigeminal contributes the infraorbital zygomatic nerves to the innervation of the face. The former, passing through the infraorbital canal, supplies both eyelids and the ala of the nose. The latter, along the lateral wall of the orbit, divides into zygomaticotemporal and zygomaticofacial

Fascia temporalis
M. temporalis
Vv. articulares mandibulae
A. et N. massetericus
A. et V. temporalis media
A. et V. temporalis superficialis
A. zygomaticus
A. meningea media
A. maxillaris interna
A. auricularis posterior
V. facialis posterior
A. carotis externa
A. occipitalis
M. pterygoideus internus
N. lingualis
A. et N. massetericus
M. masseter
N., A. et V. alveolaris inferior
V. jugularis interna
V. facialis communis
Nn. temporales profundi
A. temporalis profunda superior
Os zygomaticum
A. alveolaris superior posterior
Plexus venosus pterygoideus
Ramus profundus V. facialis anterioris
A. et N. buccinatoria
M. buccinator
A. maxillaris externa
V. facialis anterior
V. facialis anterior
A. maxillaris externa

Fig. 120. STRUCTURES IN THE DEEP LATERAL REGION OF THE FACE.

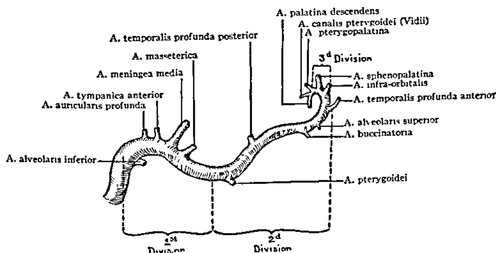


Fig. 121. DIVISIONS AND BRANCHES OF THE INTERNAL MAXILLARY ARTERY.

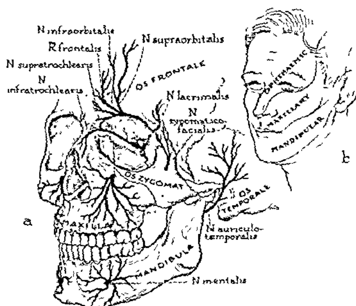


Fig. 122. COURSE AND DISTRIBUTION OF THE BRANCHES OF THE TRIGEMINAL NERVE.
a, The branches of the three divisions of the nerve; their foramina of exit and subsequent course. *b*, The areas of cutaneous innervation of the three divisions.

branches, each emerging through a foramen of corresponding name. The infraorbital nerve innervates the lower eyelid, the angle of the eye, the ala of the nose and the upper lip. The zygomatic nerve cares for the temporal region, the malar surface of the zygomatic bone and the lateral angle of the eye.

The *mandibular division* sends its auriculotemporal nerve around the condyloid process of the mandible; ascending vertically, the nerve supplies the skin of the temporal region. The mental nerve, after traversing the mandibular canal, emerges through the mental foramen; its filaments supply the skin of the chin and the lower lip.

The *maxillary nerve*, or middle branch of the trigeminal, is a sensory nerve. After leaving the semilunar ganglion it passes horizontally forward and leaves the skull through the foramen rotundum. It crosses the pterygopalatine fossa, enters the orbit through the inferior orbital fissure, and traverses the floor of the orbit to appear on the face at the infraorbital foramen.

Surgical Considerations

The areolar tissue of the deep lateral region of the face is continuous with that of the tongue, cheek and temporal regions. This continuity explains the spread of infection from one region to another. Tumors arising in the area may invade the orbit and the nasal fossae. Lymph drainage is to the upper deep cervical lymph nodes.

FACIAL NEURALGIA. The trigeminal nerve is sensory to the face and motor to the muscles of mastication; more than any other nerve of the body, it is subject to neuralgia. Pain may be present over the distribution of any or all of its divisions, but the ophthalmic and maxillary divisions are involved most frequently. When the ophthalmic division is involved, pain is usually confined to the supraorbital branch. If the maxillary division is affected, there is pain in the cheek and in the ala of the nose over the distribution of the infraorbital branch. Resection of the infraorbital nerve often gives great relief. Should disease involve the inferior alveolar branch of the mandibular division, relief sometimes follows excision of the mental branch at the mental foramen. When peripheral resection of the terminations of the main trigeminal divisions fails to cure, or when pain shifts from the territory of one division to that of another, the indication is that the semilunar ganglion is involved extensively, and its sensory portion must be destroyed to give relief.

ROUTES TO THE MAXILLARY NERVE AND SPHENOPALATINE GANGLION (OF MECKEL). The maxillary nerve lies in the highest and most inaccessible portion of the pterygomaxillary fossa. Suspended from the nerve and lying mesial to it is the sphenopalatine ganglion (of Meckel). Sensory nerves from this ganglion

are distributed, in part, to the mucous membrane of the nose, to the soft palate, tonsils, roof of the mouth and upper part of the pharynx. Resection of the zygomatic bone and the lateral wall of the orbit exposes the nerve in its course from the infraorbital groove to the foramen rotundum. Since this approach is below the internal maxillary artery, the operation may be performed without vessel injury. The nerve also may be approached and reached through the maxillary sinus.

Routes to the Inferior Alveolar Branch of the Mandibular Nerve. The mental branch of the inferior alveolar nerve can be excised at the mental foramen through the mucosa of the mouth. Excision of the inferior alveolar trunk for more extensive neuralgia may be accomplished through a trephine opening in the ramus of the mandible after incision of the overlying masseter muscle. The inferior alveolar nerve can be reached with great difficulty through the mouth (buccal approach) by an incision along the anterior margin of the ramus to the mandibular foramen, where it enters the canal with its corresponding artery.

Approach to the Semilunar (Gasserian) Ganglion. The true anatomic approach to the semilunar ganglion is a temporal-subdural route which does not involve the deep lateral region of the face. In the transtemporal approach the dura is separated from the temporal bone and base of the skull until the middle meningeal artery is seen emerging from the foramen spinosum. The artery is ligated, and cleavage is continued until the ganglion is reached. Section of the sensory root of the ganglion with conservation of the motor roots can be accomplished.

Parotid Region

Definition and Boundaries. The recess, or vertical depression which holds the parotid gland, lies behind the ramus of the lower jaw and below the base of the cranium. It has been

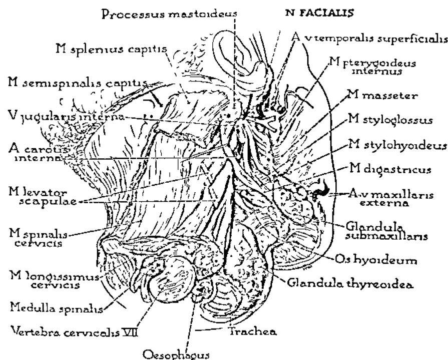


Fig. 123. STRUCTURES WHICH FORM, OR ARE CLOSELY RELATED TO, THE FOSSA FOR THE PAROTID GLAND.

The parotid gland has been wholly removed, the sternocleidomastoid muscle cut away from the mastoid process of the temporal bone (at *); the great vessels (together with arterial branches and venous tributaries) have been transected; the facial nerve has been cut just distal to the point at which the trunk divides into temporofacial and cervicofacial portions. Superficially, the parotid gland overlapped the masseter muscle in front, the sternocleidomastoid muscle behind. On deeper level it rested upon the styloid group of muscles, the styloid process (at arrow), the internal pterygoid, and digastric muscles. The following neighboring structures are also shown: muscles of the head, neck and shoulder; hyoid bone; thyroid cartilage; submaxillary gland; mastoid process of the temporal bone. (From Davis, Anson, Budinger and Kurth: Surg., Gynec. & Obst., 102: 385-412, 1956.)

considered a constituent element of the neck, but its relations place it rather as one of the regions of the face. The parotid region is bounded anteriorly by the ramus of the mandible, posteriorly by the mastoid process and anterior margin of the sternocleidomastoid muscle, and superiorly by the external auditory meatus and the zygomatic arch. The inferior margin of the recess extends to the angle of the mandible, and its mesial wall reaches to the styloid process and the lateral wall of the pharynx.

LANDMARKS. The capacity of the space is increased when the mandible is moved forward, as in protruding the chin or extending the head, and is decreased when the head is flexed. This observation is significant in clinical examination and in operations in the region. The gland cannot be felt under normal conditions, but is palpable when inflamed, enlarged by a new growth or swollen by back pressure through its duct. In such circumstances there is a change of contour in the upper neck and face, and any movement restricting the capacity of the space or pressing on the gland causes pain.

The region varies in appearance in different persons. In children, young adults and those with abundant adipose tissue it is smoothly rounded and full. In thin persons the gland has little supporting tissue on its deep aspect and sinks inward, leaving a noticeable depression behind the jaw.

PAROTID GLAND, ITS PROCESSES AND ITS DUCT. The *parotid* is the largest of the salivary glands, and completely fills the irregular parotid fascial space, being molded and adherent to its walls.

The parotid gland is traditionally credited with the possession of a distinct fascial investment. While it is true that the gland is related to layers of connective tissue which fuse

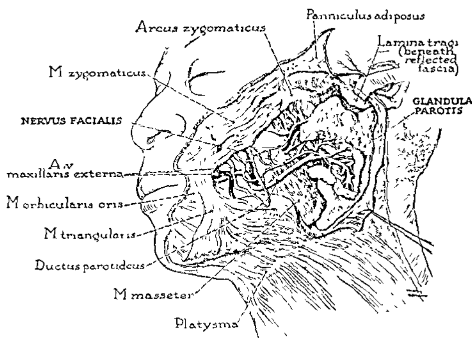


Fig. 124. FACIAL NERVE, PAROTID GLAND, PAROTID DUCT, AND FASCIA.

The outer leaf of the parotid gland has been freed and rolled aside along a curving line which, *anteriorly, marks that of* emergence of the several tributaries of the parotid duct *from the parenchyma of the gland. The tributaries* and the duct itself are closely related (*in the area pictured*) *to the buccal branch of the facial nerve. A membranous* portion of the fascia of the face, together *with contained* fascicles of the facial musculature, constitutes an outer layer of the "capsule" of the gland. *This layer* lies just beneath a stratum which may contain a moderate amount of fat (see panniculus adiposus), still present in the dissection, cranial to the zygomatic arch. Over the greater portion of its extent the parotid gland is covered on its superficial aspect by a membranous layer of fascia, which, not being capsular in the usual sense, merely passes over *the triangular* area bounded by the sternocleidomastoideus *dorsally*, by the zygomaticus *cranially*, and by *the platysma* and triangularis caudally. Before dissection, that is, *in the natural state, this fascial layer covered the area* which is bounded by the muscles named, enclosed them *as it reached their free margins*. On the deep aspect the gland rested mainly on the masseter fascia (this layer removed *in the* dissection). (From Davis, Anson, Budinger and Kurth: Surg., Gynec. & Obst., 102: 385-412, 1956.)

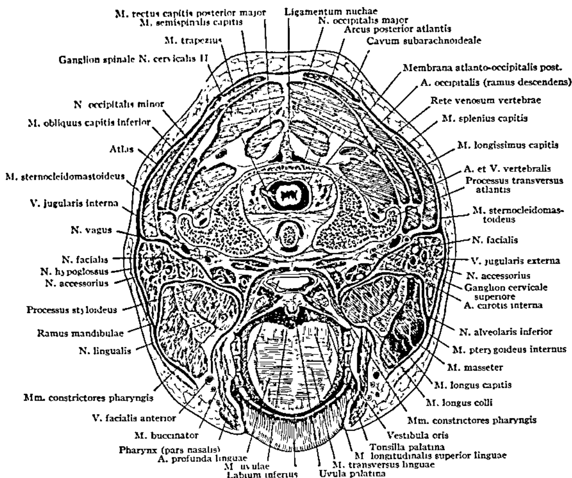


Fig. 125. CROSS SECTION OF THE HEAD AT THE LEVEL OF THE ATLAS TO SHOW THE FASCIAL AND VASCULAR RELATIONS OF THE PAROTID GLAND.

peripherally to enclose it, some qualifying statements are most certainly required.

The outer lamina of the so-called sheath is nothing more than the layer of fascia which, in the cervical and lower facial regions, contains the platysma (Figs. 124, 127). This layer is not a locally prominent entity, densely fibrous and closely adherent to the gland; rather, it is connected to the gland by numerous septa sent inward among the lobules of the gland, with strength little greater than that possessed by coverings of the other salivary glands. The inner lamina is the investing fascia of the masseter muscle. When exceptional care is exercised, it is possible to discover a stripe of fusion between these two layers along the border of the gland (Fig. 124).

The *parotid gland* lies upon the side of the face just below and in front of the external ear (Figs. 124, 127). The superficial leaf, which makes up the greater fraction of the gland, usually has the shape of an inverted triangle; not infrequently, however, this portion assumes the form of an irregular oval; superiorly, its border almost reaches the zygomatic arch; posteriorly and inferiorly, the base overlaps the sternocleidomastoid muscle; anteriorly, the apex extends over the masseter muscle, frequently prolonged along the horizontal course of the parotid duct (Fig. 127). Extending even farther forward, sometimes beyond the masseter muscle to rest upon the buccinator, an accessory glandular mass (glandula parotis accessoria) may occur (Figs. 111, 127).

The deep portion of the gland, almost always concealed by the flatter and larger superficial portion, and connected with the former by a broad isthmus, extends inward (medialward) behind the mandible, toward, or even to, the pharyngeal wall (Figs. 123, 125).

Typically, the parotid gland possesses three surfaces, namely, lateral, anterior and posterior. The superficial, or lateral, surface, which is the external part of the superficial leaf of the

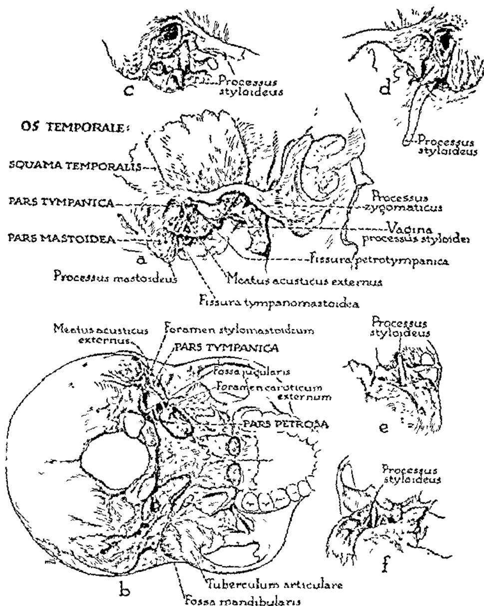


Fig. 126. SKELETAL VARIATIONS IN THE REGION OF THE STYLOID PROCESS AND THE STYLOMASTOID FORAMEN

a and *b*, Adult skulls in lateral and inferior views; *c* and *d*, adult specimens in lateral view, right and left sides, respectively. *e* and *f*, Skull of adolescent, left and right sides, respectively. In *a* and *b* a styloid process is wanting. In *c* the process extends for a distance of 1 cm. beyond the free edge of the vagina processus styloidei (indicated by arrow); in *d*, for a distance of 4 cm. beyond the sheath. In the specimen shown in *e* the process extends slightly beyond the free border of the vagina processus styloidei; in *f*, a shorter process remains concealed behind the sheath. (From Davis, Anson, Budinger and Kurth: Surg., Gynec. & Obst., 102: 385–412, 1956.)

gland, is the portion which has already been described as commonly being triangular in outline. The posterior border reaches the external acoustic meatus and the sternocleidomastoid muscle and extends inferiorly to the angle of the mandible and the posterior belly of the digastric muscle. The superior border lies below the zygomatic arch, generally matching the horizontal plane of the arch. The anterior border ascends irregularly to meet the superior border, thus forming the apex of the gland. The apex, directed forward, rests upon the masseter muscle and, when prolonged as an accessory lobe, may follow the duct to the buccinator muscle (Fig. 127). The duct usually issues from the apical part of the gland. In some cases the gland may be so large that its superficial surface descends to cover the digastric muscle and below the angle of the mandible, to come into close relation with the poste-

rior part of the submaxillary gland (Figs. 123, 124).

The anterior (or antero-inferior) surface of the gland is molded around the posterior border of the ramus of the mandible and the muscles which clothe the latter—the masseter laterally, the pterygoideus internus medially. The sulcus thereby produced in the anterior surface of the gland being, in some instances, a deep incisura, may continue posteriorly as the cleavage plane between the superficial and deep leaves.

The posterior (or posteromedial) surface is in contact with the sternocleidomastoid muscle, the mastoid process of the temporal bone, the cartilage of the external acoustic meatus, the posterior belly of the digastric muscle, the internal carotid artery, the internal jugular vein, the root of the styloid process, and the muscles (stylohyoideus, styloglossus) attached thereto (Figs. 109, 110). As the anterior and posterior surfaces of the gland meet, the part of the gland thus formed may extend medialward beyond the styloid process, toward the pharynx; this medial part, the processus retromandibularis, may constitute the bulk of the deep leaf (Figs. 110, *a*; 125).

In a recent study of the form and dimensions of the parotid gland (in 100 facial halves), the height of the gland varied between the extremes of 8.0 and 3.9 cm. (average, 6.0 cm.); the width varied between 6.5 and 2.0 cm. (average, 3.6 cm.). In an earlier series (of seventy-six glands), the height varied between 9.2 and 4.5 cm. (average, again, 6.0 cm.), whereas the extremes in width were 5.4 and 2.0 cm. (average, 3.3 cm.).

Accessory glandular masses occur rather frequently (in approximately 20 per cent of seventy-six glands examined). They are usually situated in a position superior to the main parotid duct, sometimes overlapping it (Fig. 127). The length varied between 2.3 and 1.0 cm. (average, 1.4 cm.), the height between 0.8 and 0.5 cm. (average, 0.7 cm.). The long axis regularly corresponds to that of the main duct, into which the accessory element empties by a short duct (Fig. 127).

In the plane between the superficial and deep laminae of the parotid gland "ductules"

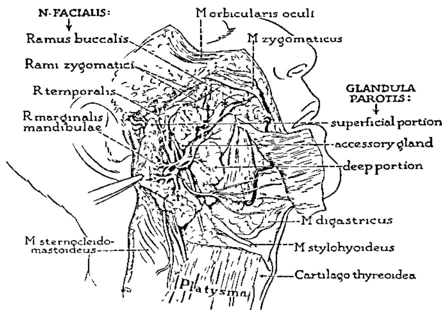


Fig. 127. FACIAL NERVE, PAROTID GLAND AND DUCT.

Removal of the superficial fascia in the region of the face inferior to the zygomatic arch, and retraction of the outer leaf of the parotid gland permit demonstration of the following features: the location of the temporal and zygomatic rami of the facial nerve in the deep substance of the fat-laden superficial fascia (thus near the muscles which they supply); the intimate relation of the several rami to the tributaries (at arrows) of the parotid duct (at •); the manner in which the rami pass to the deep aspect of the layers of facial musculature (see especially the zygomaticus and the platysma); the independence of the accessory lobe of the parotid gland (its ductule being sent into the main duct as a wholly separate unit, the parenchyma being dissociated from the deep lobe); the close relation of the buccal ramus to the parotid duct. (From Davis, Anson, Budinger and Kurth: Surg., Gynec. & Obst., 102: 385-412, 1956.)

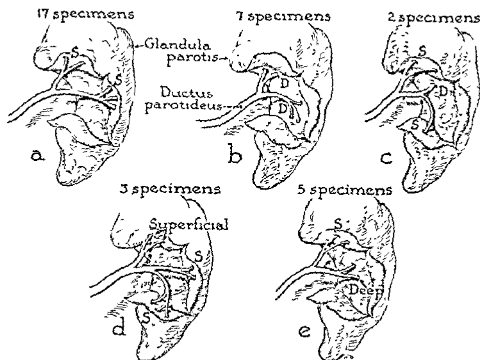


Fig. 128. TYPES OF TRIBUTARY DUCT-PATTERNS OF THE PAROTID DUCT, FROM A STUDY OF 34 CONSECUTIVE SPECIMENS. SEMISCHEMATIC.

The tributaries may arise only from the superficial lobe (*a* and *d* at *S*), from the deep lobe (*b* at *D*) or from both (*c* and *e*). *a*, Origin from the superficial leaf only (upper portion and midportion). *b*, From the deep leaf only. *c*, From the upper (cranial) and lower (caudal) portions of the superficial leaf, and from the midportion of the deep leaf. *d*, From the superficial leaf, in the latter's upper, middle and lower portions. *e*, From the superficial leaf above and the deep leaf below. (From Davis, Anson, Budinger and Kurth: Surg., Gynec. & Obst., 102: 385–412, 1956.)

of dissectable size join to form the main duct. These contributory channels may arise in any of the following ways: from the superficial leaf only, in its upper and middle portions (Fig. 128, *a*); from the deep leaf only (Fig. 128, *b*); from the superficial leaf (above and below) and from the deep leaf in its midportion (Fig. 128, *c*); from the superficial leaf only, in its upper middle, and lower parts (Fig. 128, *d*); from the superficial leaf in its upper third and from the deep leaf in its middle third (Fig. 128, *e*). These sources may be summarized as follows: the superficial leaf only in twenty instances (as in Fig. 128, *a*, *d*); from the deep leaf only in seven (as in Fig. 128, *b*); from both laminae in seven (as in Fig. 128, *c*, *e*). In the thirty-seven glands studied, ductules arose from the superficial leaf or from the superficial and deep leaves in twenty-seven of the thirty-four cases; and from the deep leaf only in the remaining seven (a proportion of approximately 4 to 1).

Near the inferior extremity (lower pole) of the parotid gland, the *anterior facial vein regularly* courses along the margin of the mandible posterior to the branches of the facial nerve, and then joins the posterior facial vein (Fig. 110). The latter structure is frequently split by the trunk of the facial nerve or by its temporofacial division. The posterior facial vein is generally posterior to the gland or is covered by the superficial leaf of the parotid gland. Usually a large retrocondylar tributary of the vein courses deep to the ramus of the mandible. The venous channels which are situated between the two laminae of the gland are small and plexiform; receiving tributaries from the parenchyma of the lobes between which they pass, the channels formed by them are directed across the masseteric fascia.

The transverse facial artery and its accompanying vein run forward beneath the superficial lobe just inferior to the zygomatic process. The external carotid artery courses deep within, or beneath the parotid gland in its superior and medial aspects. Both these vessels give off fine arterial patterns which pass between, and supply, the two lobes. Although far *from constant, the arterial plan* is less varied than the venous.

Styloid Process. Often useful in preliminary

examination of a region of prospective surgery is the presence of a constant skeletal landmark. The styloid process would seem to be a good morphologic candidate for such an office, since it is traditionally pictured as a well developed feature of the normal skull.

Actually, this osseous spine is undependable in the capacity named, since it was not only wholly absent in fifty-eight of 150 cranial halves examined, but shielded by the vagina processus styloidei in more than twenty others —a length of approximately 1 cm. often being required to bring the process downward beyond the free edge of the sheath (Fig. 126). The distribution is as follows: absence, fifty-eight; length from 0.1 to 0.9 cm., eighteen processes; length from 1.0 to 1.9 cm., forty; from 2.0 to 2.9 cm., nineteen; from 3.0 to 3.9 cm., fourteen; from 4.0 to 4.2 cm. (maximum length), one process. It is, perhaps, important to add that bilateral dissimilarity is the rule in the matter of length; and in respect to absence, it may be recorded that in eighteen skulls total absence was unilateral, while in twenty the styloid process was wanting on both sides.

The *parotid duct*, about 5 cm. in length, lies one fingerbreadth below the zygomatic arch and, when the teeth are clenched, may be rolled up and down against the tense masseter muscle. It emerges from the most anterior part of the gland and runs forward on the masseter muscle to its anterior margin (Fig. 111). The duct then passes mesially, piercing the buccinator muscle obliquely to reach the mucous membrane of the cheek. Opposite the second molar tooth, the duct opens into the mouth. The course of the duct on the masseter muscle is represented by a line drawn from the lower margin of the concha of the ear to the commissure of the lips. Injury to the duct may produce a salivary fistula. Inflammatory lesions in the mouth may spread backward along the duct and involve the gland.

Infection in the parotid gland, *parotitis*, may be blood-borne or may occur by direct extension from the buccal cavity or from duct obstruction. In nonsuppurative parotitis, or mumps, the painful, tender tumor disappears after a few days, but in septic or metastatic parotitis the swelling persists. Abscess may set in with the alarming symptoms of bacteremia. Early incision is demanded only after intensive radiotherapy (x-ray and radium) has failed to abort the infection (Fig. 116)

VESSELS AND NERVES IN AND ABOUT THE PAROTID GLAND. The most important structures entering and leaving the gland are the facial nerve and its branches, the posterior facial vein, and the external carotid artery with its terminals, the superficial temporal and internal maxillary arteries.

The *external carotid artery* does not run in the inferior portion of the gland, but enters higher up, on a level with the junction of the middle and lower thirds of the ramus of the mandible. It traverses the substance of the gland from this point upward and gives off its terminal branches at the level of the neck of the mandible. Within the gland the external carotid artery is deep to the posterior facial vein, which, in turn, is deep to and crossed by the facial nerve. Occasionally the external carotid artery runs between the parotid gland and the pharynx.

The *lymph nodes* of the parotid region are divisible into two groups. Superficial to the parotid sheath lie the nodes of the anterior auricular (preauricular) group, which drain the temporal and frontal regions of the scalp, the outer portions of the lids and the outer ear. Scattered through the gland substance, although chiefly situated near its surface, lie the nodes of the parotid group, which drain the upper and posterior parts of the nasopharynx, the soft palate and the middle ear. Because of the frequency of inflammation in the areas drained, a parotitis must not be considered primary (mumps) until secondary lesions in tributary parts have been ruled out—as, for instance, the parotitis of otitis media.

An abscess arising in connection with the preauricular lymph nodes points superficially. The outer covering of the parotid gland is strong enough to resist the outward progress of an abscess in the parotid lymph nodes. The abscess tends to advance upward in the line of least resistance, although such progress is resisted by gravity. It is much more likely to invade the thinner mesial wall of the parotid space and to point in the pharynx or buccal cavity, or burst through the lower confines of the parotid space and enter the neck. Infections may invade the external auditory meatus and the temporomandibular joint.

The auriculotemporal and facial nerves traverse the upper portion of the parotid. The *auriculotemporal nerve* is a sensory branch of the mandibular nerve, supplying the skin in

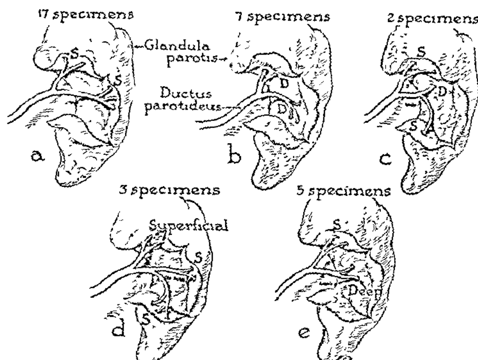


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Styloid Process. Often useful in preliminary



Fig. 130. PATIENT SHOWING MARKED FACIAL DEFORMITY BECAUSE OF INJURY TO MANDIBULAR BRANCH OF LEFT FACIAL NERVE.

The line of excision for removal of an upper neck tumor is outlined. (From Pollack: Arch. Surg., 68: 81–6, 1954.)

usually about half the size of the upper division; its branches and anastomoses are far less complex than those of the temporofacial part.

PAROTID GLAND TUMORS AND THE FACIAL NERVE. By far most operations on the parotid gland are for tumors. The most common benign one is the "mixed tumor," which will recur locally unless completely excised. About one third of parotid tumors are malignant and therefore require wide excision. In many of these cases the nerve cannot be spared.

Since the facial nerve passes between the leaves of the parotid gland (Figs. 110, 111, 127), it is apparent that to remove a tumor adequately and yet not injure the nerve, the nerve must first be exposed for safety.

To develop the facial nerve, two procedures are advised. One is to locate the nerve as it emerges from the anterior edge of the parotid gland (Fig. 131), and dissect the nerve filaments posteriorly, at the same time developing a layer of adjacent normal tissue about the tumor as it is excised. The second and more common procedure is to find the main trunk of the facial nerve as it emerges from below the inferior margin of the ear canal and dissect the branches forward as the tumor is developed. A valuable instrument in this regard is a nerve stimulator, which can be applied to strands of tissue having the appearance of the nerve and proving it by producing characteristic twitching of the muscles of the nerve's distribution.

It is important to save all branches of the facial nerve in doing a parotid gland tumor excision. One of the most difficult to conserve is the marginal mandibular branch (Fig. 132). If it is injured, a partial paralysis of the orbicularis oris muscle occurs with a most noticeable facial deformity (Fig. 130). This should be avoided. Byars, whose dissection of a parotid tumor is shown in Figure 131, first emphasized the finding of the marginal mandibular branch running downward in close proximity to the posterior facial vein, which courses through the substance of the gland and leaves the gland near the anterior central portion of the lower tip. This relationship is diagrammed in Figure 132. The exposure of this nerve while performing a radical neck dissection is shown in Figure 131.

PAROTID GLAND CALCULI. These occur less commonly in the parotid gland than in the submaxillary salivary gland. For parotid stones a direct approach must be made with either removal of the stone or excision of a block of scarred tissue containing it. Exposure of the parotid duct is necessary, along with location of a fairly large accompanying filament of the facial nerve (Fig. 124), which supplies innervation to the middle third of the face. When the stone is felt, the duct is opened through a longitudinal incision and the stone removed. The duct is then carefully closed with fine suture material.

front of the ear, and extending upward through the temporal region to the vertex of the skull. Its compression in tumors of the parotid gland causes exquisite pain, which radiates over the temple and associated scalp, even as far the vertex of the skull.

Surgical Considerations

Facial Nerve and Parotid Gland. The facial nerve comes into relationship with the parotid gland (Figs. 110, 127) immediately upon leaving the stylomastoid foramen. The nerve passes in front of the posterior belly of the diagastric muscle and lateral to the styloid process, the external carotid artery and the posterior facial vein (Fig. 110); then, upon reaching the posterior border of the ramus of the mandible, it breaks up into its terminal branches, which course to the musculature of facial expression (Figs. 110, *b*; 127).

In every instance, in a recent series of 350 cervicofacial dissections, the trunk of the nerve separated into two main divisions, the temporofacial and cervicofacial portions (Fig. 129). This point of bifurcation of the facial nerve lies posteriorly and slightly medial to the ramus of the mandible and superiorly two thirds of the distance between the external angle of the mandible and the temporomandibular articulation.

In all instances the temporofacial portion of the nerve is the larger of the two primary divisions. In the proximal part of its course this division lies between the lobes of the parotid gland, proximal to the point of its separation into branches. The cervicofacial division is

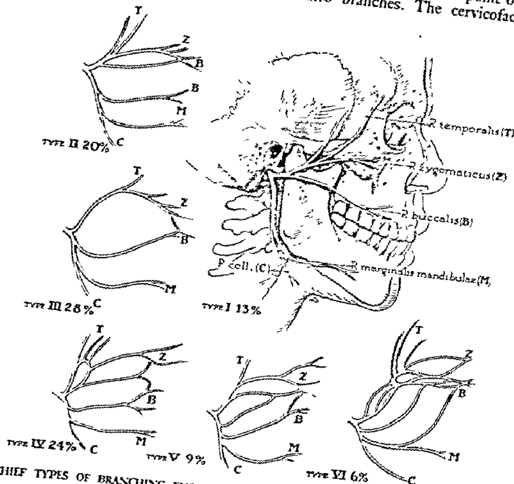


Fig. 129. CHIEF TYPES OF BRANCHING ENCOUNTERED IN 350 CERVICOFACIAL HALVES SCHEMATICALLY SHOWN, AS OF THE RIGHT SIDE OF THE HEAD.

Note that Types III, IV, V, and VI together represent almost 70 per cent of specimens. Type I, Absence of anastomosis between the branches of the two divisions (temporofacial and cervicofacial) of the facial nerve; although, regularly pictured, actually an uncommon type. Type II, Anastomoses within the temporofacial division. Type III, Anastomosis between chief divisions. Type IV, Two anastomotic loops within the temporofacial part. Type V, Two loops from the cervicofacial division, intertwined with branches of the temporofacial. Type VI, Extensive intermixture. (From Davis, Anson, Budinger and Kurth: Surg., Gynec. & Obst., 102: 385-412, 1956.)

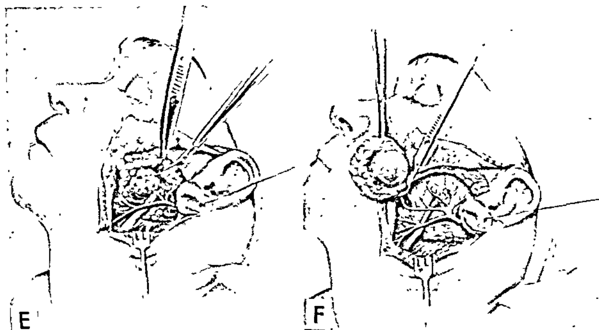


Fig. 131. OPERATION ON THE PAROTID GLAND WITHOUT ADEQUATE EXPOSURE OF THE AREA INVITES PARALYSIS OF THE FACIAL NERVE.

A, An incision as indicated with wide reflection of the skin flap provides this exposure. The resulting scar is eventually as unnoticeable as any properly executed transverse incision in a flexion crease of the neck. *B*, Diagrammatic representation of skin incision, parotid gland, facial nerve and posterior facial vein relationship. The divisions of the facial nerve vary, but the association of the posterior facial vein and the anteriorly placed lower division of the nerve is reasonably constant. This division of the nerve may cross the vein on its deep or superficial side. *C*, Skin flap is reflected widely: As the lower pole of the parotid gland is separated from the sternocleidomastoid muscle, the posterior facial vein is encountered emerging from the anterior central portion of the tip of the lower pole of the gland. This vein continues inferiorly deep to the sternocleidomastoid muscle. If a vein is found which passes inferiorly in the platysma muscle superficial to the sternocleidomastoid muscle, it is one origin of the external jugular vein, and dissection should be continued forward to locate the posterior facial vein. *D*, The lower division of the facial nerve is easily located by searching immediately in front of the posterior facial vein within the substance of the parotid gland. *E*, As the lower division of the facial nerve is traced superiorly, it will be found to cross the posterior facial vein on its superficial side in most instances. It sometimes crosses deep to it. At this point the nerve is large and joins its trunk almost immediately. In operations for benign tumor removal a simultaneous nerve-tumor dissection is performed. When possible, a margin of normal parotid tissue is left on the tumor. At those points where nerve fibers are closely applied to the tumor the dissection is on the nerve rather than on the tumor. *F*, In most instances a considerable portion of the facial nerve is displayed by the completion of tumor removal. There should be no doubt in the surgeon's mind as to the integrity of the nerve. (From Byars: Ann. Surg., 136: 412-21, 1952.)

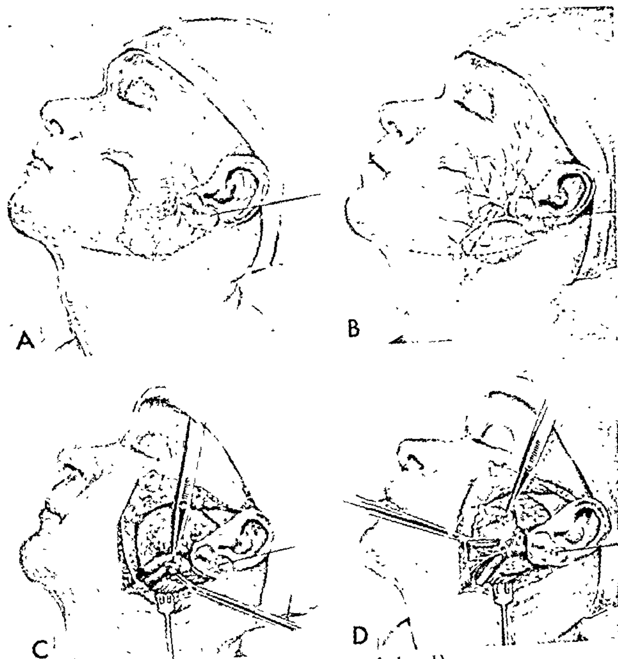


Fig. 131. (See facing page for legend.)

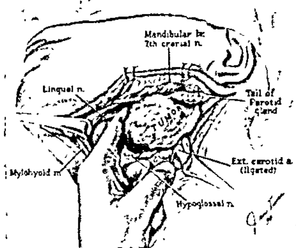


Fig. 134. EXCISION OF RETROMANDIBULAR PAROTID TUMOR.

Mandibular branch of the facial nerve reflected out of the operative field for safety. Facial artery and vein ligated and divided. External carotid ligated. Submaxillary gland excised to give access to the pharyngomaxillary space where the bulk of the tumor is located and enucleated, if the lesion is benign. Fixation and failure to find a cleavage plane usually signify malignancy. Because of edema and difficulty in breathing postoperatively a tracheostomy is usually done in each case. (From Morfit: Arch. Surg, 70: 906–13, 1955.)

Retromandibular Parotid Tumors. About 80 to 85 per cent of the parotid gland lies external to the ascending ramus of the mandible. The small pharyngeal prolongation hooks around the posterior margin of the mandible and extends for variable distances medial to this structure (Fig. 133). Tumors may develop from this retromandibular portion and form bulges or lumps along the lateral pharyngeal wall. Growth is slow, so that later there is little more than pressure, some interference with the airway and dysphagia. The histology of these tumors differs in no way from that of other portions of the parotid. Response to radiation therapy is poor, and surgical excision is required (Fig. 134).

Fig. 132. AN IMPORTANT ANATOMICAL LANDMARK IN AVOIDING INJURY TO THE FACIAL NERVE IS THE RELATIONSHIP OF THE MARGINAL MANDIBULAR BRANCH TO THE POSTERIOR FACIAL VEIN. THIS DIAGRAM FURTHER EMPHASIZES THE RELATIONSHIP STRESSED BY BYARS IN FIGURE 131.

Emerging from beneath the central inferior pole of the gland in the neck, not on the cheek, the nerve frequently runs on the surface of the vein, occasionally a few millimeters anterior to it, or crosses it diagonally. Identified in this area first, it can be traced forward beneath the platysma muscle and reflected away from the operative field if the area is not involved in malignancy. Anteriorly this nerve may divide into several smaller branches, all or some of which can be spared to avoid the distressing deformity shown in Figure 130. (From Pollack: Arch. Surg., 68: 81–6, 1954.)

Fig. 133. RETROMANDIBULAR PAROTID TUMORS.

A, Normal retromandibular portion of parotid. *B*, Usual position of parotid tumors. *C*, Retromandibular parotid tumor. (From Morfit: Arch. Surg., 70: 906–13, 1955.)

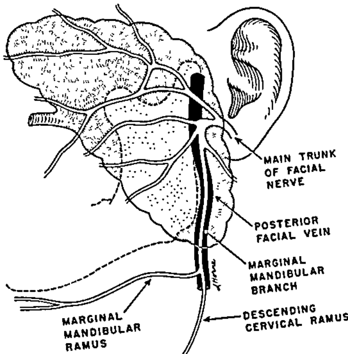
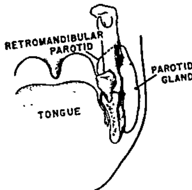
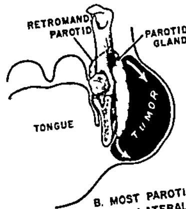


Fig. 132

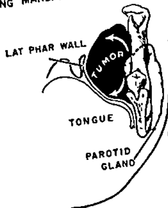
RETROMANDIBULAR PAROTID TUMORS



A. ALTHOUGH MOST OF PAROTID GLAND LIES EXTERNALLY, A SMALL PORTION LIES POST. & MEDIALLY TO ASCENDING MAND. RAMUS



B. MOST PAROTID TUMORS ARISE LATERAL TO BONE. AS THEY INCREASE IN SIZE THEY PRODUCE CLASSICAL EXT. PREAURICULAR. SWELLING.



C. TUMORS ARISING FROM RETROMANDIBULAR PORTION EXPAND MEDIALLY DUE TO UNYIELDING LAT. BONY WALL. NO EXT. MASS APPEARS AND ONLY SYMPTOM IS BULGING OF LAT. PHAR. WALL.

Fig. 133

GINGIVAE, OR GUMS. The term "gingiva" is used to indicate the composite mucous membrane and submucous tissue which is attached firmly to the alveolar processes and to the dental arches (Fig. 103). In the newborn it covers the toothless borders of the jaws. Its submucous base is directly continuous with the alveolar periosteum, which dips down into each tooth socket to form the root membrane, or pericementum. The gingiva is fairly vascular, but not very sensitive. A portion of the gingiva projects into each interdental space and surrounds the necks of the teeth.

ALVEOLAR PROCESSES OF THE JAWS, AND THE ALVEOLAR OR TOOTH SOCKETS. The teeth are *rooted in the alveolar cavities or sockets* (Fig. 103). The divergence of the roots and their twisted state serve to maintain them mechanically in their beds. Inflammation of the root membrane, or pericementum, early follows root caries and dental periostitis. The alveolar cavities, particularly in the lower jaw, are much nearer the outer than the inner table, as is evidenced by their palpable bulging into the vestibules. The thinness of this outer plate explains the easy perforation of root abscesses to the vestibular surfaces of the gums. This also is the cause of frequent fracture of the outer plate in tooth extraction. The alveolar process is the point of origin of the tumor, *epulis.*

Surgical Considerations

ALVEOLAR OR ALVEOLODENTAL ABSCESSES. An alveolodental abscess is a circumscribed pus cavity located at the apex of a tooth; it usually is caused by the death of the pulp (Fig. 136). The infection in the pulp cavity invades the space between the root and the socket and may progress until it reaches the compact tissue on the alveolar surface of the jaw. The pus from the abscess generally escapes through the surface offering least resistance, namely, the external alveolar plate, lateral to the apex of the *affected tooth. In so doing it may lift up the* periosteum for a sufficient distance to cause considerable necrosis of underlying bone. The pus finally may escape through a sinus remote from the point of origin. In the lower jaw the force of gravity and the pressure of accumulating pus may make a path between the periosteum and soft tissues, or between the periosteum and bone, with final discharge on the neck beneath the chin or jaw (Fig. 136). An abscess in connection with the third lower *molar (wisdom tooth) may penetrate the lateral* tissues at the angle of the jaw, or occasionally

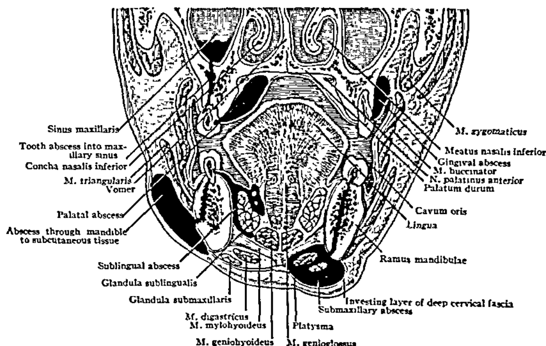


Fig. 136. FRONTAL SECTION THROUGH THE FACE AND UPPER NECK TO SHOW THE VARIETIES OF ALVEOLAR ABSCESS.

CHAPTER 4

Regions within the Buccal Cavity

The buccal cavity and its contents are divided conveniently into vestibule and gingivodental region, palate region, sublingual and glossal regions (Fig. 135). As a whole, it includes the space between the nasal cavities above, the neck below, the lips in front and the pharynx behind.

Vestibule of the Buccal Cavity and Gingivodental Arches

The gingivodental arches divide the buccal cavity into the vestibule and the buccal cavity proper.

VESTIBULE. The vestibule is lined by the mucous membrane from the lips, the cheeks and from the outer alveolar surface of the jaws. Where the mucous membrane of the lip is reflected to the alveolar processes of the jaws, horseshoe-shaped grooves are formed, known as the superior and inferior vestibular fornices. The maxillary sinuses do not descend to the upper fornix, but can be reached surgically through an opening at this point (p. 75). At the level of the first or second upper molar tooth the buccal orifice of the parotid duct opens upon the lateral wall of the vestibule (p. 135).

The vestibule communicates with the buccal cavity proper through the interdental spaces and through the openings between the rami of the mandible and the last molar teeth. The latter communication can be utilized for the introduction of food into the buccal cavity proper when there is a locking of the jaws, as in tetanus or in ankylosis of the temporomandibular joint.

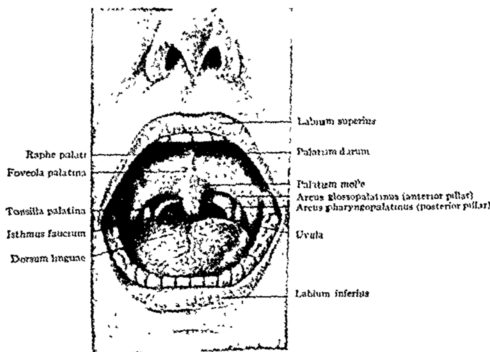


Fig. 135. BUCCAL CAVITY.

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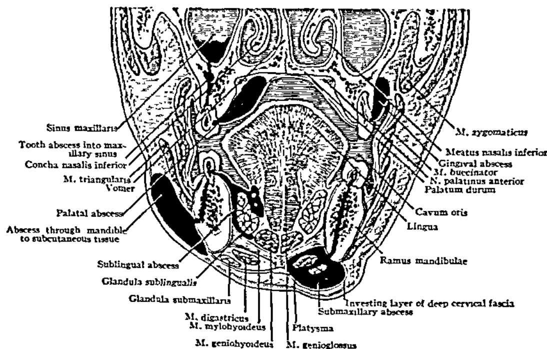


Fig. 136. FRONTAL SECTION THROUGH THE FACE AND UPPER NECK TO SHOW THE VARIETIES OF ALVEOLAR ABSCESS.

may burrow downward into the neck, forming large pus cavities in the submaxillary region. The pus may take a mesial course and discharge through the buccal surface of the gum.

Abscesses are less likely to occur in the upper jaw, where there is an abundant blood supply. The pus from abscesses in the upper jaw may extend into the nasal cavity or perforate the maxillary sinus and establish an empyema. However, the pus may pass directly through the external alveolar plate and form a sinus on the cheek, or discharge around the root socket.

The underlying principle of treatment is the opening and draining of the pus cavity with the least sacrifice of normal tissue. Simple removal of gangrenous dental pulp, which frequently is the origin of the abscess, may suffice in those cases in which there has not been serious bone destruction. This usually is impractical, and it becomes necessary to limit the destruction of tissue and reach the focus by surgical means, either by trephine of the alveolar plate or by extraction of the tooth. Tooth extraction in acute abscess may develop into an extensive sepsis, absorption taking place at the extracted tooth socket. Treatment of abscesses which have burrowed downward into the neck is evacuation by external incision.

DENTAL CARIES. A breaking down of the enamel exposes the dentin to the destructive action of microorganisms, which cause progressive destruction of the teeth, advancing from the exterior to the interior. A tooth may undergo disintegration in part or entirely.

PYORRHEA ALVEOLARIS. Pyorrhea alveolaris is an exuding of pus from the dental alveoli. It is primarily a disease of the bony substance, the pericementum, and usually manifests itself as a chronic suppurative inflammation. Secondarily, the process involves the gingiva and the walls of the alveoli. It causes loosening and extrusion of the teeth, a discharge of pus from their alveolar margins, and caries of the alveolar process. Recession of the gums takes place until the teeth lose their gingival and alveolar connections and fall out. Upon the loss of the teeth, the inflammatory symptoms subside immediately. The point of greatest clinical importance is prevention, which is based on unremitting care of the teeth, to keep the gums free from inflammatory change.

EPULIS. Epulis usually implies any tumor of the gum, but is specifically that growth which originates from the periosteum at the border of the alveolar process. It occurs most frequently anterior to the molar teeth. The gum tissue is involved secondarily as the tumor develops. This common oral tumor primarily is benign, but, subjected to continuous irritation, may present malignant characteristics.

SYPHILIS OF THE TEETH. The temporary teeth in hereditary syphilis show malformations dependent upon perversion of nutrition. The enamel may be lacking or chalky, the dentin soft, or the teeth irregular in shape and position. The permanent central incisors in hereditary syphilis are known as *hutchinsonian teeth*. They are shorter than normal teeth, and their free borders are narrow, notched and bevelled. The first molar teeth often are reduced in size.

Palate Region

The embryology of the palate is bound up intimately with the developmental changes about the lip, the details of which are described on page 112.

DEFINITION AND BOUNDARIES. The roof of the mouth, or the palate, separates the main buccal cavity from the nasal cavity and from the nasal portion of the pharynx (Fig. 137). Its anterior two thirds comprise the hard palate; its posterior third, the soft palate.

LANDMARKS. The hard palate is vault-shaped, the soft palate veil-like; and the whole is designed for the role it plays in deglutition and phonation. In a person breathing normally the soft palate hangs semivertically between the buccal and pharyngeal cavities. In the act of sucking, it is brought into contact with the base of the tongue, thereby stopping all communication between the mouth and pharynx. Swallowing lifts it out of its vertical position and spreads it as a horizontal septum between the buccal and nasal portions of the pharynx, thus preventing food from entering the nose by way of the posterior nares. This action is lost in diphtheritic and other paralyses of the muscles controlling the soft palate. The free margin of the soft palate forms an arch, extending from one side of the pharynx to the other, from the middle and highest point of which projects the variable-sized, pendant *uvula*. Laterally, the free margin continues into the posterior or *pharyngopalatine arch* (posterior pillar of the fauces), and forward into the

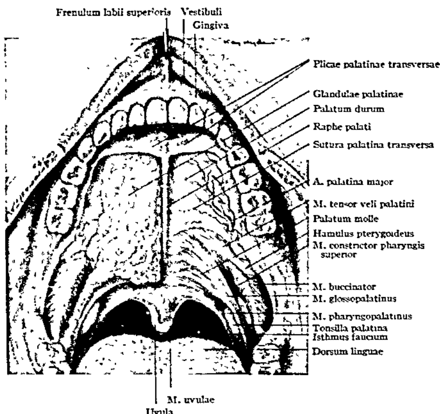


Fig. 137. SUPERFICIAL AND DEEP STRUCTURES OF THE PALATE AND TONSIL REGIONS. The palatine glands have been removed on the left side.

glossopalatine arch (anterior pillar of the fauces, Fig. 137).

STRUCTURES OF THE HARD PALATE. The hard palate is a horizontal plate covered by a dense structure formed by the periosteum and mucous membrane of the mouth (Fig. 137). The tissue contains a large number of palatine glands, intrinsic nerves, and blood vessels. The hard palate is a frequent site of disease in tertiary syphilis.

The buccal palatine mucosa is remarkably thick, especially at the alveolar margin, where it is continuous with the gingiva. This relationship explains the extension of dento-alveolar abscesses to the palatal vault. The soft tissues covering the buccal surface of the hard palate are fused into a closely knit layer, but in cleft palate surgery the whole (mucoperiosteum) may be detached readily from the bone. A ridge running sagittally on the hard palate, often mistaken for a tumor, is an excessive developmental heaping up of bone along the suture between the palatine processes of the maxillae.

STRUCTURES OF THE SOFT PALATE. The soft palate is a mobile, musculomembranous septum about 1 cm. thick, attached to and extending backward from the hard palate. The palatine mucosa covers its superior and inferior surfaces and winds about its free border. Deep to the mucosa is the submucosa, so loosely attached to the underlying structures, especially at the uvula and pillars, that edema may develop easily. The dense palatine aponeurosis, to which the several muscles of the palate are attached, forms the framework of the soft palate. The anterior part of the soft palate is made up almost exclusively of this aponeurosis, covered on its buccal surface by an extremely thick layer of glands (Fig. 137); it contains no muscle fibers.

The muscles which help form the soft palate are the pharyngopalatine, glossopalatine and uvular muscles, and the levators and tensors of the palate. The pharyngopalatine and glossopalatine muscles, which form the pillars or arches of the tonsil, are important in tonsillectomy (p. 158). In cleft palate operations for complete fissure these muscles have a strong

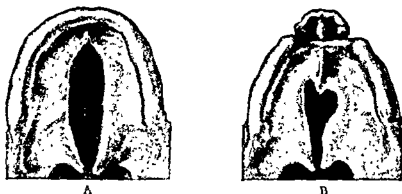


Fig. 138. VARIETIES OF CLEFT PALATE.

A shows a cleft extending through the soft and hard palates. In *B*, there is a cleft in the soft palate, extending into the hard palate; the premaxillary process is entirely separate from the maxillary bones, a condition usually coexisting with double harelip.

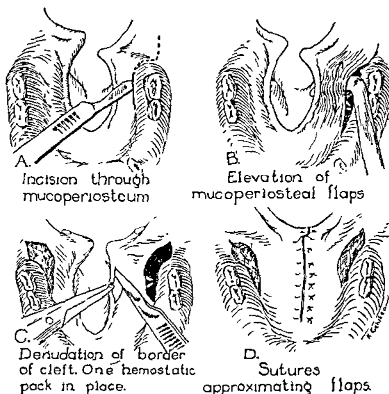


Fig. 139. OPERATIVE CLOSURE OF CLEFT PALATE.

(After Blair.)

tendency to retract laterally the parts of the soft palate into which they insert. The tensor veli palatini muscle also is important in postoperative retraction, and may require division to reduce the strain on the repaired soft palate.

VESSELS AND NERVES. The arteries to both the hard and the soft palates come chiefly from the internal maxillary through the descending palatine branches, which run down through the pterygopalatine canal and forward in the angle between the vertical and horizontal processes of the maxillae, almost in contact with the bone (Fig. 137). In repair of the cleft palate (uranoplasty) these arteries must be protected to nourish the flaps of tissue used in closing the cleft. This may be done by making the incisions of the mucous membrane as close as possible to the gingival border. As the incision is carried posteriorly, it should wind about the last molar tooth to avoid injury to the major palatine artery where it leaves the palatine canal. No vessels are endangered in division of the tendon of the tensor veli palatini muscle.

Surgical Considerations

CLEFT PALATE. Harelip and cleft palate occur with such frequency, cause such faulty articulation, and affect the spirit of the patient to such an extent that any measure promising relief should be instituted as early as possible. Cleft palate, which may or may not be accompanied by harelip, single or double, invariably is congenital (Figs. 104, 138). The fissure or fissures so formed are brought about by an arrest in normal development. In any case, there is not absence of tissue, but failure in union of tissue.

If the maxillary bud fails to unite with the frontonasal process, there is a cleft extending from the mouth to the lateral part of the upper lip or even to the eye and beyond. If failure to unite occurs only at the extremity of the frontonasal process, the cleft extends from the lateral part of the lip toward or into the nostril, and a simple harelip results. If, as rarely occurs, the two globular tips of the frontonasal process fail to unite, there is a median fissure. Should the mandibular processes fail to unite, a median cleft of the lower lip, and even of the jaw and tongue, may result.

CLEFT PALATE OPERATIONS. The object in the treatment of cleft palate is to establish normality. The procedure is mechanical closure of the gap or fissure. *Staphylorrhaphy* is the name given to the operation which approximates and unites a cleft in the soft tissue, and *uranoplasty* to that which remedies a defect in the bone. The features common to operations designed to close the fissure by the suture method are freshening of the margins of the cleft, mobilizing and approximating the soft parts to close the cleft, and suturing of the apposed margins (Fig. 139).

It may be necessary to adopt measures to eliminate countertraction, which tends to cut out sutures and pull apart the newly apposed margins. This may be accomplished by cutting the levators of the soft palate and the pharyngopalatine and glossopalatine muscles, or sectioning the tensor veli palatini muscles. The approximation operation can be done only early in infancy, preferably within the first three months. After this period, ossification has progressed so far that lateral incisions in the mucoperiosteum do not permit sufficient mobilization of the flap.

Floor of the Mouth, or Sublingual Region

DEFINITION AND BOUNDARIES. Each sublingual region is a deep groove in the floor of the mouth, and lies between the mandible and the root of the tongue on the mylohyoid and hyoglossus muscles (Fig. 140). Its posterior boundary is the glossopalatine arch, or the anterior pillar of the tonsil. The sublingual region is separated from the submaxillary region by the mylohyoid and hyoglossus diaphragm.

LANDMARKS. The middle fold, or frenum, of the tongue is seen best by elevating the tongue (Fig. 140, *A*). If, in the newborn, the frenum interferes with proper movements of the tongue because of its extensive attachment, it may be divided. At the base of the frenum is the salivary caruncle with the openings of the submaxillary ducts and the principal duct for the sublingual gland. Beginning at the caruncle and running backward on both sides of the base of the tongue is an elevated crest of mucous membrane, the sublingual fold. The minor sublingual ducts (of Rivinus) open by orifices on this ridge and are scarcely visible. The sublingual salivary gland is the most important structure in the area. Sublingual adenomas, carcinoma or diffuse sublingual abscess may distort the area.

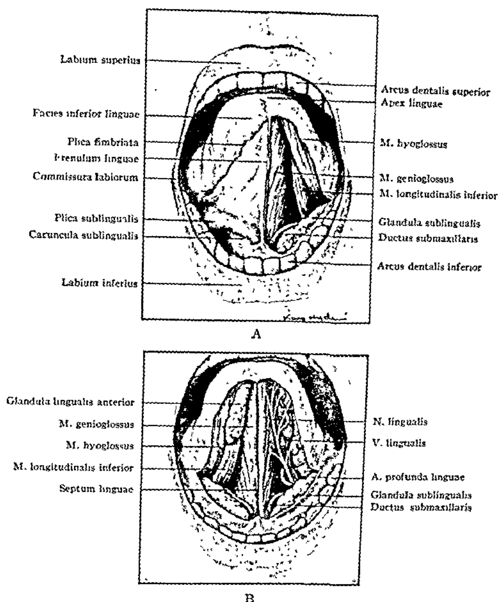


Fig. 140. SUPERFICIAL AND DEEP STRUCTURES IN THE SUBLINGUAL REGION.

A, The mucosa is left intact on the right side, on the left, the region has been cleared of the vessels and nerves. *B*, The vessels and nerves have been removed on the right side, and on the left the vessels and nerves are *in situ*.

CONTENTS OF THE SUBLINGUAL REGION. Each compartment encloses the sublingual gland, the anterior prolongation of the submaxillary gland, the submaxillary duct, the lingual and hypoglossal nerves, and the sublingual vessels (Fig. 140, *B*).

The *sublingual gland* is the smallest of the salivary glands and rests against the sublingual fossa of the mandible, close to the symphysis, on the mylohyoid muscle. Its posterior extremity is in contact with the anterior prolongation of the submaxillary gland. Thus both salivary glands form an almost continuous mass, lying partly in the submaxillary region and partly in the sublingual region. Between the sublingual gland and the root of the tongue run the submaxillary duct, the lingual and hypoglossal nerves and the sublingual vessels.

The *anterior prolongation of the submaxillary gland* is wedged between the mylohyoid and hyoglossus muscles and contains the submaxillary duct (Fig. 141).

The *submaxillary duct* is not difficult to catheterize at its orifice at the sublingual caruncle; this duct, despite its thinness, is very resistant. Its canal occasionally is obstructed by a calculus, which can be felt through the buccal mucosa and can be removed easily. The structures of the space lie in the midst of areolar tissue, designed to allow free movement of the tongue. Infection readily develops and spreads within this tissue.

M. pterygoideus internus
Ramus mandibulae
M. masseter
N. lingualis
Ganglion submaxillare
N. sublingualis
Ductus submaxillaris (Whartoni)
Glandula submaxillaris
A. maxillaris externa
M. stylohyoideus
Lingua
Rami linguales n. lingualis
Caruncula sublingualis
Ductus sublinguales minores
Glandula sublingualis
Mandibula
M. digastricus
M. mylohyoideus
A. submentalis
V. submentalis
V. facialis anterior

Fig. 141. LATERAL VIEW OF THE SUBLINGUAL REGION.
The body of the mandible has been removed.



Fig. 142. SAGITTAL SECTIONS THROUGH THE SUBLINGUAL AREA TO SHOW THE LOCATION OF SUBLINGUAL ABSCESSES.

A, Muscles and spaces in the floor of the mouth. 1, Mylohyoid muscle; 2, space between geniohyoid and mylohyoid muscles; 3, geniohyoid muscle; 4, space between geniohyoid and genioglossus muscles; 5, genioglossus muscle. *B*, External approach to space between the mylohyoid and geniohyoid muscles. *C*, Approach through the mouth to space between geniohyoid and genioglossus muscles. (Courtesy of Dr. A. C. Furstenburg, from Coller and Yglesias: Surg., Gynec. & Obst., 60: 277–90, 1935.)

Surgical Considerations

LUDWIG'S ANGINA. This term is used to cover a variety of serious predominantly streptococcal infections involving the floor of the mouth. The primary infection is commonly one of the inner aspect of the lower lip, the lower gingivae or teeth.

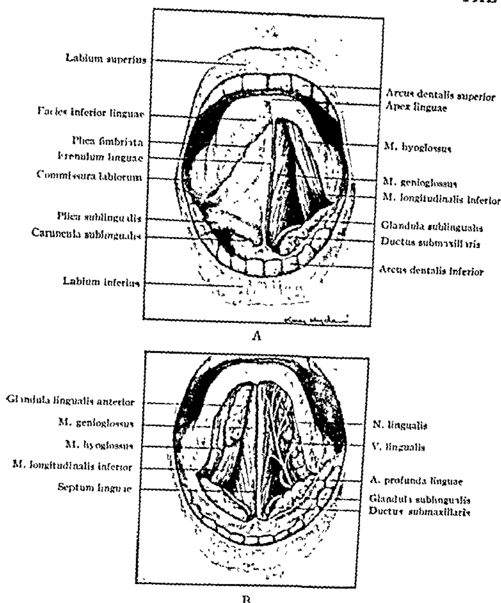


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The *sublingual gland* is the smallest of the salivary glands and rests against the sublingual fossa of the mandible, close to the symphysis, on the mylohyoid muscle. Its posterior extremity is in contact with the anterior prolongation of the submaxillary gland. Thus both salivary glands form an almost continuous mass, lying partly in the submaxillary region and partly in the sublingual region. Between the sublingual gland and the root of the tongue run the submaxillary duct, the lingual and hypoglossal nerves and the sublingual vessels.

The *anterior prolongation of the submaxillary gland* is wedged between the mylohyoid and hyoglossus muscles and contains the submaxillary duct (Fig. 141).

The *submaxillary duct* is not difficult to catheterize at its orifice at the sublingual caruncle; this duct, despite its thinness, is very resistant. Its canal occasionally is obstructed by a calculus, which can be felt through the buccal mucosa and can be removed easily. The structures of the space lie in the midst of areolar tissue, designed to allow free movement of the tongue. Infection readily develops and spreads within this tissue.

and in front of the pharynx. The superior portion is free and mobile, and covered by mucosa.

There are two divisions of the mobile portion: an anterior, or buccal, and a posterior, or pharyngeal. The buccal part of the tongue is disposed almost horizontally, and the pharyngeal base vertically, forming part of the anterior wall of the pharynx.

The buccal part is demarcated from the pharyngeal part by a distinct V-shaped groove, the terminal sulcus, the apex of which corresponds to a depression on the posterior surface of the tongue, the *foramen caecum*.

STRUCTURES. The main substance of the tongue is composed of *intrinsic lingual muscles*. The *extrinsic lingual muscles*, arising from the mandible, hyoid bone, styloid process and soft palate, are inserted into the main intrinsic muscle mass of the tongue. The *mucous membrane* over the anterior two thirds of the tongue is closely adherent to the underlying musculature. These muscles elevate, depress, protrude or retract the tongue. The muscle mass of the tongue is kept from falling backward by its attachment to the symphysis of the jaw. Profound anesthesia which relaxes all muscles of the tongue is likely to allow the organ to fall back and obstruct the larynx by depressing the epiglottis. During anesthesia, therefore, the lower jaw should be carried well forward to advance the base of the tongue and keep it from interfering with the epiglottis. When this procedure is not sufficient to prevent suffocation, direct traction on the tongue is necessary.

Below the tip it forms a fold in the median line, the *frenum*.

At the apex of a V-shaped row of circumvallate papillae (Fig. 145) is a small depression, the *foramen caecum*, the remains of an embryonic tubular downgrowth in the floor of the primitive pharynx. It is the beginning of the fetal thyroglossal duct, from which the thyroid gland is developed.

The surface of the pharyngeal portion of the tongue is studded with masses of lymphoid tissue which make numerous elevations called, in aggregate, the lingual tonsil. This is a part of the general peribuccal ring of lymphatic tissue (of Waldeyer) (p. 156). The mucous membrane on the pharyngeal part of the tongue is continuous with that covering the epiglottis and forms the glossoepiglottic folds and fossae.

VESSELS AND NERVES. The principal *arteries* supplying the tongue are branches of the lingual artery which pass forward mesial to the

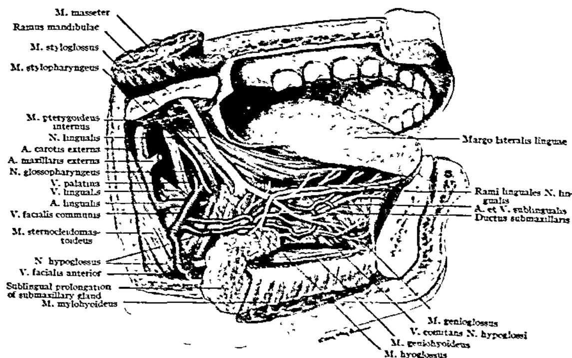


Fig. 144. DEEP LATERAL VIEW OF THE LINGUAL REGION, WITH THE BODY AND PART OF THE RAMUS OF THE MANDIBLE CUT AWAY AND THE SUBLINGUAL GLAND REMOVED.

The mylohyoid muscle has been reflected downward.

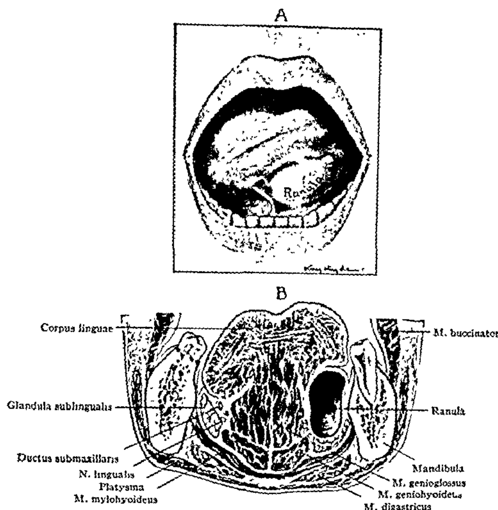


Fig. 143. RANULA.
A, The ranula bulging upward from the sublingual area. *B*, The ranula in frontal section.

Before the use of sulfonamides and antibiotics the process often spread rapidly to become a massive cellulitis extending along the lymphatics and fascial and muscle planes to the submaxillary and submental areas and down the neck, and, more importantly, moving posteriorly to involve the larynx. Serious interference with respirations then occurred, so that deaths from pulmonary infection were once common. Elevation of the tongue, redness and edema of the floor of the mouth, and brawny induration of the upper neck were the clinical characteristics. Not infrequently, pus accumulated in the sublingual area both above and below the geniohyoid muscle, and drainage was accomplished as shown in Figure 142. The quick use of antibiotics brings about a rapid resolution of an early infection, so that full-blown Ludwig's angina is rarely seen.

RANULA. A ranula is a retention cyst of the submaxillary or sublingual ducts (Fig. 143). When first formed, it contains saliva which later degenerates into a mucus-like substance. A true ranula may appear on either side of the floor of the mouth. True mucous cysts do not occur in the mucous glands of the floor of the mouth. In true ranula it usually is advisable to remove both the cyst and the sublingual gland. A portion of the cyst wall, however, may be removed and the interior of the cyst cauterized.

CALCULUS IN THE SUBLINGUAL GLAND AND DUCTS. The sublingual gland may require removal because of an embedded calculus. The calculus can be palpated between a finger in the mouth and the thumb below the angle of the jaw. A simple incision through the mucous membrane suffices for removal of the calculus.

Region of the Tongue

DEFINITION AND BOUNDARIES. The tongue is attached to the floor of the mouth, the mandible and the hyoid bone, so as almost to fill the mouth cavity (Fig. 144). It lies below the palate region, above the floor of the mouth,

and in front of the pharynx. The superior portion is free and mobile, and covered by mucosa.

There are two divisions of the mobile portion: an anterior, or buccal, and a posterior, or pharyngeal. The buccal part of the tongue is disposed almost horizontally, and the pharyngeal base vertically, forming part of the anterior wall of the pharynx.

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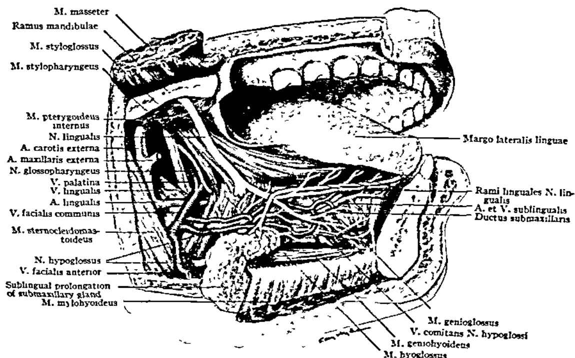


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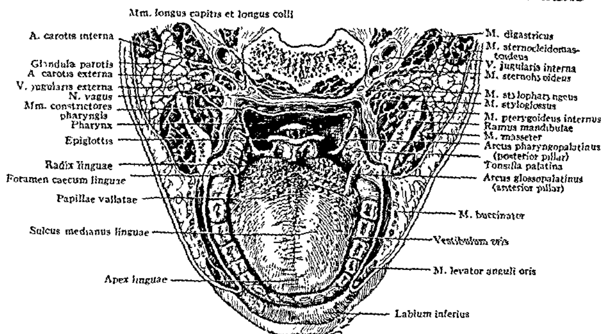


Fig. 145. CROSS SECTION THROUGH THE BUCCAL CAVITY AND THE ORAL DIVISION OF THE PHARYNX.

hyoglossal muscle and then continue to the apex of the tongue as the deep lingual artery.

The *lymphatics* are numerous and originate in an extensive network in the submucosa and in a smaller network in the muscle substance. The lymph vessels of the anterior portion of the tongue drain into the submental and submaxillary glands and into the upper deep cervical chain. From the margins and dorsum of the tongue behind the apex and extending back to the vallate papillae, the lymph vessels pass to the submaxillary and upper deep cervical glands. The lymphatic system from the base of the tongue drains into the deep cervical group. Carcinoma of the tongue, when confined to the lip or the posterior third of the organ, involves glands of both sides because of the decussation of the lymph paths. The motor *nerve* to the tongue is the hypoglossal (Fig. 144).

Surgical Considerations

MACROGLOSSIA AND ANKYLOGLOSSIA (TONGUETIE). *Macroglossia* is a term applied to a more or less uniform enlargement of the tongue, in contradistinction to true tumor formation. The superabundance of tissue frequently is congenital, and in this form may show an excess of fibrous, glandular or lymphatic elements. The enlargement occurs mainly in the base of the tongue, where the lymphatic elements are most numerous. The tongue may attain extraordinary dimensions and be forced outside the mouth, even causing deformities of the teeth.

Ankyloglossia (tonguetie) is the result of a congenital shortening of the frenum which holds the tongue to the floor of the mouth. Protrusion of the tongue is hampered, and the frenum may require division lest articulation be impaired.

CARCINOMA OF THE TONGUE AND FLOOR OF THE MOUTH. Cancer of the mouth and lip tends to remain confined to the head and neck for long periods, thus presenting a great chance of cure even after cervical metastases have occurred.* This is well borne out by statistics showing that patients dying of head and neck carcinoma have no cancer below the clavicles in 80 per cent of cases. Few areas present such an unusual opportunity for cure by eradication of the local lesion and an adequate neck gland dissection. The latter is the accepted treatment in nearly all the cancer hospitals, clinics and most of the radiological institutes in the world. Microscopically proved metastases to the neck were found by Sugarbaker** in the following incidences: lip, 31 per cent; gum, 35 per cent; cheek, 40 per cent; tongue and floor of the mouth, 63 per cent; nasopharynx, 80 per cent. Since the cure rate of some of the local lesions by surgery, radiation therapy or a combination of both is high, the ultimate fate of these patients will depend upon the success in controlling the cervical metastases. Figure 146 shows the essential steps in a supraomohyoid

* Brown, J. B., and McDowell, Frank: Neck Dissections. Springfield, Ill., Charles C Thomas, 1954.

** Sugarbaker, E. D.: Surgery, 18: 608

and a radical neck gland dissection, which should be used in all operable cases. In others a program of radiation therapy is indicated. Hayes Martin's* figures from the Head and Neck Service of Memorial Hospital, New York, are impressive (Table 1).

LINGUAL THYROID. Failure of migration of the median primordium from its origin in the base of the pharynx will result in thyroid tissue located at the base of the tongue between the epiglottis and the circumvallate papillae. An example of this and the anatomical approach for dissection is shown in Figure 146. Special care should be taken to avoid injury to the mandibular branch of the facial nerve (Figs. 109, 110, 132).

* Martin, H.: Cancer of the Head and Neck. American Cancer Society, Inc., 1949.

Table 1. Five-Year Cure Rates in Mouth Cancer (Period 1935-1942)

Site of Primary Lesion of Cancer	*Percentage of 5-year Cure Rate in All Cases (both Early and Advanced)*	*Percentage of 5-year Cure Rate in Early Cases (Primary Less than 2 Cm.)*
Lip	70	86
Tongue	30	55
Floor of Mouth	20	50
Mucosa of Cheek	24	60
Palate	30	57
Gums	32	38
Tonsil	20	40

Note that when the primary lesions are less than 2 cm. in diameter, the chance of cure is almost double that which can be obtained in all comers when the more advanced cases are included.

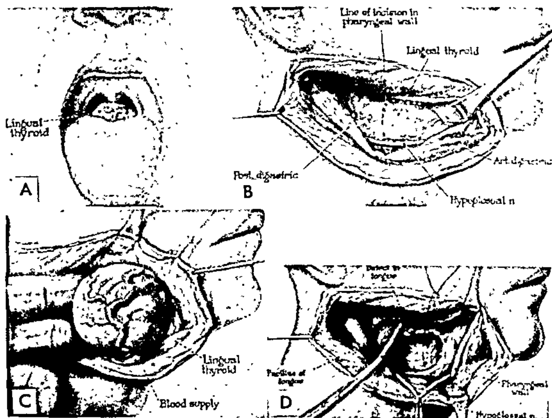


Fig. 146. THYROID TUMOR.

A, Lingual thyroid seen with the tongue pulled forward. *B*, Exposure of the lateral pharyngeal wall. In carrying out this approach, care should be taken to avoid injury to the mandibular branch of the facial nerve (Fig. 109, p. 137). The tumor lies immediately beneath the mucous membrane. Incision in the pharynx is indicated by the dotted line. *C*, The tumor and tongue displaced into the wound. *D*, Defect in the tongue left after complete excision of the tumor. (From Ward, Cantrell and Allan: Ann. Surg., 139: 536–45, 1954.)

CHAPTER 5

Tonsillar Region and Pharynx

Palatine Tonsil Region or Fossa

DEFINITION AND BOUNDARIES. The faucial tonsillar region, although anatomically located in the anterolateral pharynx and properly belonging to it, is more particularly an intermediate area between the buccal cavity and the oral division of the pharynx (Fig. 147). The anterior and posterior boundaries of the fossa are its two pillars or arches. These diverge downward from the soft palate, the anterior pillar to fuse with the lateral wall of the tongue, and the posterior pillar to spread out on the side wall of the oral division of the pharynx. The glossopalatine muscle is the essential muscle of the anterior pillar or arch, and the pharyngopalatine muscle that of the posterior pillar or arch. The deep tonsillar recess between the pillars has as its apex the soft palate, as its base the lateral wall of the oral division of the pharynx, and as its floor the intrapharyngeal aponeurosis of the side wall of the pharynx.

PALATINE TONSIL. The palatine tonsil, like the lingual and pharyngeal tonsils, varies considerably in size and shape. A study of its development serves to explain this variation.

Soon after birth the tonsil undergoes a characteristic irregularity of growth, the ultimate shape and size of the organ depending on the amount of lymphoid tissue present. The maximum growth generally takes place in the two lower lobes, which project into the pharynx and obscure the smaller upper lobes lying deep in the *supratonsillar recess* (Fig. 147). The recess might be termed the intratonsillar fossa, since the tonsillar tissue extends upward, beneath and around it into the soft palate.

On drawing the anterior pillar of the fauces forward and outward, a triangular fold can be seen passing backward to the tonsil. This fold is the posterior and inferior prolongation of the mucous membrane from the anterior pillar. It covers a thin layer of fibrous tissue continuous with the capsule of the tonsil. The upper or supratonsillar part of the fold extends across the intratonsillar recess as the *semilunar fold* and forms the mesial fold of the recess. The remainder of the fold is known as the *triangular plica*.

There are numerous *varieties of tonsil*, from the type deeply embedded between the pillars, to that enlarged so as almost to reach the median line (Fig. 148). From the surgical standpoint, the embedded tonsil is much more difficult to enucleate than is the pedunculated tonsil, most of which is exposed and easy of access. The greater part of the "buried tonsil" can be made prominent by pressing on the anterior pillar, or by the patient's gagging during the examination. Much of the hidden tonsil extends upward into the soft palate, above and deep to the intratonsillar recess. A large part may extend downward to the tongue in the form of infratonsillar lymphoid nodules, and frequently a portion extends forward for a variable distance beneath the triangular fold and the anterior pillar. Like all lymphoid structures, tonsils diminish in size after puberty, and atrophy in old age.

The *tonsillar crypts* are ingrowths of the surface epithelium and vary greatly in number and size. They extend varying distances into the lymphoid tissue of the tonsil. The tonsil is separated from the pharynx by its *capsule*, a specialized portion of the intrapharyngeal aponeurosis. The capsule covers all but the mesial surface of the gland and sends strong fibrous trabeculae into the lobular substance, affording paths to blood vessels and nerves. The tonsil capsule is separated from the superior constrictor muscle of the pharynx by lax connective tissue. When the tonsil is pulled forcibly into the oropharynx by a volsella during tonsillectomy, the pharyngeal muscle is not drawn out with it. A cleavage plane for enucleation of the gland is thus afforded, and the tonsil

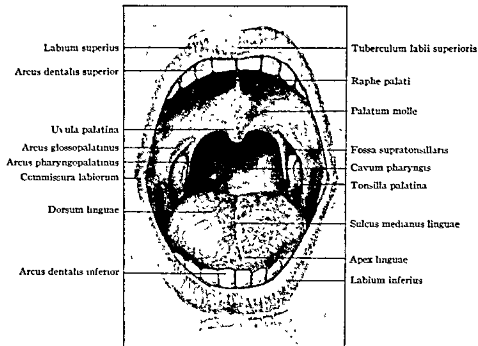
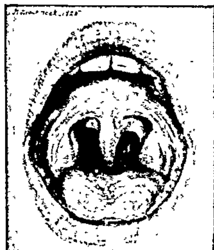


Fig. 147. BUCCAL CAVITY AND TONSIL REGION.


a


b

Fig. 148. TYPES OF TONSIL.

a, Buried tonsils. *b*, Pedunculated tonsils. (From Birkett in Jackson and Coates: The Nose, Throat, and Their Diseases.)

is removed with the part of the pharyngeal aponeurosis which forms the tonsil capsule. After repeated attacks of peritonsillar infection (quinsy) the tonsil capsule may become so densely adherent to the constrictor muscle that the tonsil can be removed only by sharp dissection.

INFRATONSILLAR LYMPHOID NODULES. Lying on the lateral wall of the pharynx and tapering down to a free end is a *pharyngeal branch of the palatine tonsil.* The upper extremity of this branch may be disclosed directly by deep depression of the tongue, and indirectly by the laryngeal mirror or by palpation. The *lingual branch of the tonsil*, in reality, is a continuous structure, extending from one side to the other with but a notch to mark the median raphe. The *lymphoid apron* is perhaps the most important division of the infratonsillar nodules. It is a wide, thick band of lymphoid tissue

partially framed by the lingual branches of the tonsils. It overlies nearly the entire base of the tongue and supports the *lingual tonsil* near its center.

It is interesting to note that the lymphoid masses, commonly known as *recurrent tonsils*, really are only the upper parts of the trunks which unite the tonsillar branches. Even when the palatine tonsils have been enucleated perfectly, large segments of the branches may, in the course of time, work their way upward into the empty fossa, where, particularly during attacks of acute inflammation, they appear to be parts of the original tonsils. To the uninitiated, such apparent postoperative defects reflect discredit on the surgeon's skill and prompt unjustifiable criticism.

The palatine tonsil, with this scattered circular band of lymphoid tissue and the tubal and pharyngeal tonsils, forms the *lymphoid ring* (of Waldeyer). This peribuccal ring acts possibly as a first line of defense against bacterial invasion of the nasal and buccal passages; the second line is the lymph nodes draining the area.

Relations of the Palatine Tonsil. The lateral surface, or hilus, of the tonsil is applied through its capsule to the constrictor muscle of the pharynx. The vessels and nerves enter the gland in the areolar tissue around the gland. In this potential space peritonsillar abscess (quinsy) develops. The pharyngeal wall separates the tonsil from the parapharyngeal space.

The larger part of the *parapharyngeal* or *mandibulopharyngeal space* is occupied by the vagus, hypoglossal, glossopharyngeal and spinal accessory nerves, the internal carotid artery and the internal jugular vein. The relations of the tonsil differ in the prestyloid and retrostyloid divisions of the parapharyngeal space.

In the anterior (prestyloid) area the tonsil is related to the areolar tissue between the pharyngeal wall and the internal pterygoid muscle. Only over the retrostyloid portion has the tonsil any possible relation to the internal carotid artery and internal jugular vein. Only under most abnormal conditions does the *internal carotid artery* lie immediately lateral to the tonsil. Ordinarily it is on a plane well posterior to the tonsil and is separated from it by the stylopharyngeus muscle. Moreover, an interval of 1.5 cm. or more separates the tonsil from these structures. The interval between the artery and tonsil is such that the gland may be removed for carcinoma through a posterior incision in the neck without injury to the vessels, provided the operative field is kept well forward of the styloid muscles and the posterior belly of the digastric muscle.

The *external carotid artery* lies about 2 cm. from the lateral pharyngeal wall, and is separated from it by a portion of the parotid gland and the musculature about the styloid process. It must be borne in mind, however, that a deeply embedded and enlarged tonsil is on a more lateral plane than is the remainder of the pharyngeal wall and, as such, is more closely related to the large vascular trunks than a description of the relations of a normal tonsil implies.

It is important to realize that the *external maxillary (facial) artery* occasionally has an important relation to the postero-inferior portion of the gland. This artery, after branching from the external carotid artery, frequently takes an upward bend deep to the ramus of the mandible. When this bending is marked, the arterial loop thus formed may come into close relation with the inferior portion of the tonsil, permitting possible injury to it in tonsil enucleation. The superior constrictor muscle of the pharynx is the only muscle interposed between this artery and the tonsil. Hemorrhage in this region almost always comes from injury to either the ascending palatine or tonsillar branches of the external maxillary artery where they pierce the superior constrictor muscle of the pharynx and supply the palatine tonsil.

Tonsil relations to the parapharyngeal space show that anterior peritonsillar abscesses may invade the anterior or prestyloid portion of the space. Early evacuation of the abscess lessens the chance of parapharyngeal involvement and possible invasion of the posterior vascular structures of the space.

Vessels and Nerves. The *arterial supply* to the palatine tonsil, while derived from several sources, comes ultimately from the external carotid trunk. The ascending palatine and tonsillar branches of the external maxillary artery enter the gland from below. The gland receives a supply posteriorly from the ascending pharyngeal branch of the external carotid artery and anteriorly from small branches of the lingual artery. The supply from above is from the descending palatine branch of the internal maxillary artery. These vessels ordinarily are small, but occasionally are sufficiently

large to cause troublesome hemorrhage. The tonsillar branch of the external maxillary artery usually is the largest vessel and passes upward on the outer wall of the pharynx, traversing it to supply the tonsil and soft palate. When the branches are cut as they enter the capsule of the tonsil, the hemorrhage usually is of little consequence; but when a vessel is severed in the pharyngeal wall before it breaks into its small branches, the hemorrhage may be alarming. Tonsillectomy hemorrhage is most severe when tags of tonsils are left in place, the explanation possibly being that the severed vessel cannot retract and thrombose.

The *lymph supply* to the tonsil is particularly abundant. From the collecting vessels over the lateral tonsillar surface, the drainage is through the wall of the pharynx to the deep cervical glands a little below the angle of the jaw. Consequently these glands are enlarged in inflammatory or carcinomatous lesions of the tonsil. One of these glands, situated just behind the angle of the jaw beneath the anterior edge of the sternocleidomastoid muscle, is enlarged so constantly in tonsillar infection as to be termed the tonsillar lymph node (*cf.* Fig. 154).

Surgical Considerations

PERITONSILLAR ABSCESS, AND ITS INCISION. *An abscess may arise in the peritonsillar connective tissue* (outside the capsule of the tonsil) after acute suppurative tonsillitis. This abscess (quinsy) commonly occurs in the anterior portion of the peritonsillar space and probably

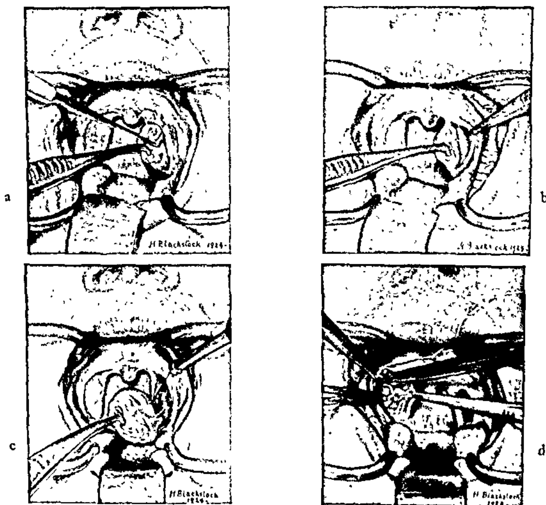


Fig. 149. DISSECTION METHOD OF TONSILLECTOMY. FOUR STEPS.

a, The tonsil is grasped by forceps; the knife is inserted into the tissue behind the anterior pillar, thus releasing the latter from the tonsil. *b*, The part of the tonsillar capsule which lies behind the tonsil is not exposed. *c*, The wire loop of the snare is now applied to the pedicle of the tonsil. *d*, After extirpation the tonsillar fossa is explored for bleeding points. (From Birkett in Jackson and Coates: The Nose, Throat and Ear and Their Diseases.)

partially framed by the lingual branches of the tonsils. It overlies nearly the entire base of the tongue and supports the *lingual tonsil* near its center.

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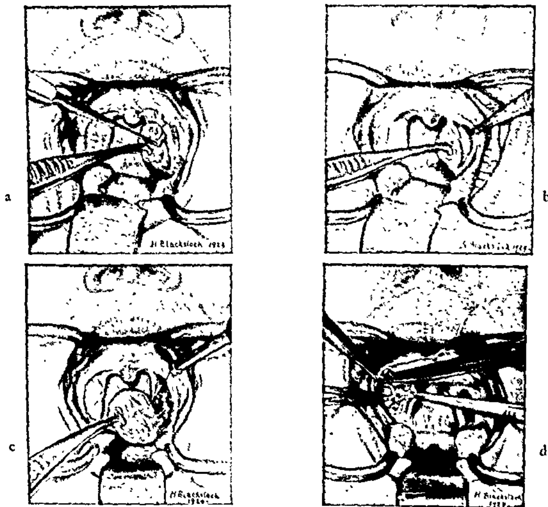


Fig. 149. DISSECTION METHOD OF TONSILLECTOMY. FOUR STEPS.

a, The tonsil is grasped by forceps; the knife is inserted into the tissue behind the anterior pillar, thus releasing the latter from the tonsil. *b*, The part of the tonsillar capsule which lies behind the tonsil is not exposed. *c*, The wire loop of the snare is now applied to the pedicle of the tonsil. *d*, After extirpation the tonsillar fossa is explored for bleeding points. (From Birkett in Jackson and Coates: The Nose, Throat and Ear and Their Diseases.)

results from direct extension from suppurative foci in the tonsillar crypts. The abscess may invade the pharyngeal wall and the structures of the parapharyngeal space.

Peritonsillar abscess usually is opened through the mouth by a stab incision about 1 cm. lateral to the free border of the anterior pillar at its upper attachment, and sufficiently deep to enter the peritonsillar space. Vessels encountered here are small, and hemorrhage from them usually stops spontaneously or can be arrested easily by pressure. The incision sometimes is made midway on a line which unites the base of the uvula to the last upper wisdom tooth. In many instances the abscess seems to point mesially, where it can be evacuated by plunging a hemostat between the tonsil and one or the other of its pillars. The use of the anatomic route in tonsillectomy encounters no essential structures.

Tonsillectomy by Dissection. The main feature in any removal of the tonsil is total excision of the gland with its capsule (Fig. 149). To accomplish this, the mucous membrane folds uniting the tonsil to the anterior and posterior pillars must be incised. The tonsil is grasped by a tenaculum and is drawn mesially into the pharynx, so that the interval between the tonsil and its anterior pillar can be recognized clearly. A sharp dissector is then carried through this interval along the anterior pillar just beneath the mucous membrane covering the tonsil. Retraction of the anterior pillar and blunt dissection expose the bluish-white capsule. In continuing the enucleation, close contact with the capsule must be maintained. By pushing the areolar tissue outward, the upper pole is exposed readily and is drawn downward with grasping forceps. At this stage the tonsil is freed by sharp or blunt dissection from its attachment to the posterior pillar, leaving it attached only to the inferior part of the fossa. The tonsil, with its capsule intact, then can be separated, either by scissors or snare, from the fascia holding it in its fossa. The snare is in common use because its crushing action tends to thrombose the vessels. It has the added advantage that, when applied about a partially enucleated tonsil, it tends to follow the tonsillar capsule, removing it more satisfactorily than the tonsillotome, which cuts through a resistant mass rather than follows its irregularities. Finger dissection or enucleation, while successful in the hands of those accustomed to it, is likely to be attended by considerable trauma. It is difficult to separate the tonsillar capsule from the pharyngeal bed when repeated attacks of inflammation have made their union almost fibrous.

Region of the Pharynx

Definition and Boundaries. The pharynx is a vertically placed musculomembranous tube situated behind the nasal fossae, the mouth and the larynx (Fig. 150). It is roofed by the base of the skull, and is continued below into the esophagus opposite the sixth cervical vertebra. Its lateral and posterior walls are formed by the three constrictor muscles, which are arranged like three flower pots fitted into one another. The continuity of the anterior wall is interrupted by the choanae (posterior nares), the entrance into the buccal cavity, and the superior orifice of the larynx. Lesions are manifested clinically by disturbances in breathing, swallowing and phonation.

Divisions of the Pharynx. The pharynx has three divisions: nasopharynx, oropharynx and laryngopharynx.

The *nasopharynx* is roughly cube-shaped and is the direct posterior continuation of the nasal fossae. The posterior nares form the boundary between the two areas. The nasopharynx is bounded below by the soft palate, and the region can be examined by a finger introduced through the mouth and carried upward behind that structure. In swallowing, the soft palate (p. 144) is applied against the posterior pharyngeal wall, and effectively partitions the nasopharynx from the oropharynx. This arrangement keeps food from entering the nasopharynx and nose. During respiration the soft palate hangs vertically downward, placing the nasal and oral divisions in broad communication.

In the anterior wall of the nasopharynx the posterior border of the nasal septum (p. 64) can be felt, and, on each side of it, the finger can be passed through the choanae to touch the posterior extremities of the middle and inferior conchae. The basilar part of the occipital bone forms the roof of the nasopharynx; the regularity of the sinus varies with the shape and size of the sphenoid sinuses. A little below the roof of the posterior wall the anterior arch of the atlas may be palpated. The *pharyngeal tonsil* lies on this wall, and overgrowth of its lymphoid tissue (adenoids) may fill up the

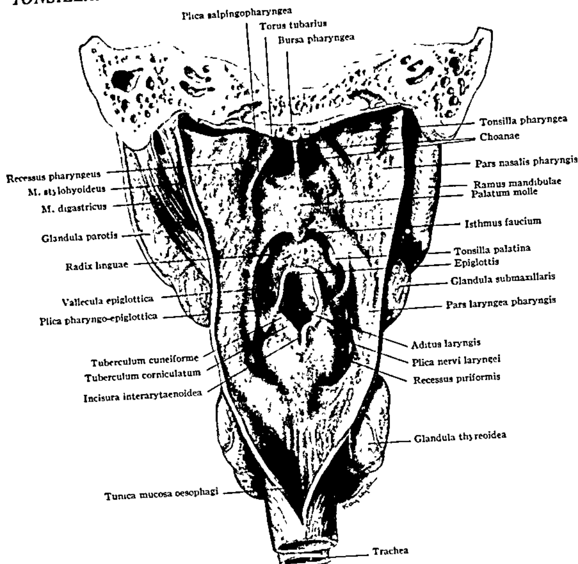


Fig. 150. POSTERIOR VIEW OF THE PHARYNX AND ESOPHAGUS.
The posterior wall of the pharynx is opened.

nasopharynx and hinder or completely obstruct nasal breathing.

On the lateral wall the bulging orifice of the auditory (eustachian) tube leads upward, backward and laterally to the tympanic cavity (Figs. 64, *A*; 75, *d*,). The posterior lip of the opening is a prominent elevation (eustachian cushion) derived from the cartilaginous portion of the tube, behind which lies the pharyngeal recess (fossa of Rosenmüller). Beneath the mucous membrane of the pharyngeal opening of the tube is a considerable amount of lymphoid tissue, the *tubal tonsil* (of Gerlach). When the orifice of the tube is occluded, as by adenoids, the air in the tympanic cavity is absorbed gradually and deafness results. The unyielding character of the walls of the nasopharynx favors packing of the cavity for the arrest of nasal hemorrhage.

The *oropharynx* is the posterior continuation of the mouth cavity. Although, anatomically, the tonsillar region is a part of the lateral wall of the oropharynx, the tonsils are of such clinical importance as to have been discussed as a separate region. When the mouth is closed, the anterior wall of the oropharynx consists of the posterior vertical part of the tongue. A retropharyngeal abscess causes a forward bulging of the posterior pharyngeal wall, which may interfere with respiration and cause symptoms not unlike those associated with adenoids and enlarged palatine tonsils.

results from direct extension from suppurative foci in the tonsillar crypts. The abscess may invade the pharyngeal wall and the structures of the parapharyngeal space.

Peritonsillar abscess usually is opened through the mouth by a stab incision about 1 cm. lateral to the free border of the anterior pillar at its upper attachment, and sufficiently deep to enter the peritonsillar space. Vessels encountered here are small, and hemorrhage from them usually stops spontaneously or can be arrested easily by pressure. The incision sometimes is made midway on a line which unites the base of the uvula to the last upper wisdom tooth. In many instances the abscess seems to point mesially, where it can be evacuated by plunging a hemostat between the tonsil and one or the other of its pillars. The use of the anatomic route in tonsillectomy encounters *no essential structures.*

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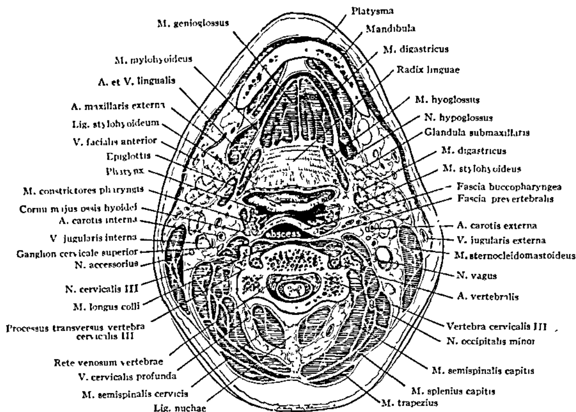


Fig. 152. CROSS SECTION AT THE LEVEL OF THE THIRD CERVICAL VERTEBRA TO SHOW THE BULGING OF A RETROPHARYNGEAL ABSCESS INTO THE PHARYNX.

The abscess has arisen from infection of the retropharyngeal lymph nodes and is in contradistinction to retropharyngeal abscess of spinal tuberculous origin.

treme care must be observed lest there be aspiration of the septic contents.

Surgical Considerations

NASOPHARYNGEAL EXAMINATION. Examination of the nasopharynx is made by reflecting light directly upon a rhinoscopic mirror held behind the soft palate while the patient breathes quietly through his nose. The mirrored image reflects the posterior nares, the septum, and the posterior extremities of the superior, middle and inferior conchae. On each side is seen the pharyngeal opening of the auditory tube, the auditory eminence, and the pharyngeal fossa (of Rosenmüller). Examination may be made with the pharyngoscope passed into the nasopharynx through the nose.

PHARYNGEAL TONSIL (ADENOIDS). Adenoids appear as simple enlargement of the pharyngeal tonsil. The term usually is applied to lymphoid tissue of sufficient amount to cause obstruction to normal breathing. Adenoids of moderate size appear as rounded masses on the posterior walls of the nasopharynx. When large, they cover the upper part of the septum, as may be seen in the rhinoscopic mirror. Their size may be such as to fill the nasopharynx and extend below the level of the soft palate, making posterior rhinoscopic examination impossible. When acutely inflamed, they become considerably enlarged, and contain exudate similar to that found in the crypts of the palatine tonsils in the course of a follicular tonsillitis.

The symptoms of excessive adenoid vegetation are caused by auditory tube and nasal obstruction and by extension of the inflammation to contiguous structures. With a virulent infection there may be an acute adenoiditis with marked systemic reaction. The infection may extend up the auditory tube into the middle ear (otitis media) (p. 90). Surgical removal is the only treatment for adenoid obstruction, and the whole of the nasopharyngeal vault should be cleared of lymphoid tissue.

Adenoids may be confused with pedunculated nasopharyngeal polyps, which orig-

The *laryngopharynx* is the lowermost division of the pharynx, and is separated from the oropharynx by the pharyngo-epiglottic fold. It lies below the level of the hyoid bone. At the center of the laryngopharynx is the raised opening of the larynx below the epiglottis, on each side of which is the piriform sinus. Behind the laryngeal opening the laryngopharynx narrows down to join the cervical esophagus. The relation of the pharynx to the laryngeal orifice explains how foreign bodies in the pharyngeal recesses cause laryngeal symptoms.

Structure of the Pharyngeal Wall. The pharyngeal walls present mucosal, submucosal (intrapharyngeal aponeurosis) and muscle layers (Fig. 150).

The *mucous membrane* is vascular and readily inflamed, and, in acute or chronic catarrhal disease, secretes an obnoxious discharge from its many glands. It may present tuberculous or syphilitic ulceration or be the point of origin of an epithelioma. Within it lie the masses of lymphoid tissue which play an important role in the nasopharynx, from both the infective and obstructive standpoints.

In the posterior and lateral walls of the pharynx the cellular tissue between the mucosa and muscularis is differentiated into an *intrapharyngeal aponeurosis*. This layer is strongest and densest in the floor of the tonsillar fossa. From it is derived the capsule of the tonsil.

The *pharyngeal muscles* are divided into constricting and elevating groups. The superior, middle and inferior constrictors overlap one another from below upward and contract the cavity of the pharynx. The elevating muscles run longitudinally and raise the pharynx and larynx. The pharyngeal musculature may be paralyzed in bulbar brain lesions or in diphtheria. Since these muscles are concerned vitally in swallowing, their paralysis allows food to be forced upward into the nasal fossae or downward through the larynx.

Peripharyngeal Spaces. The upper pharynx is separated from the surrounding structures by lateral and retropharyngeal spaces (Fig. 151).

Each *lateral space*, roughly defined between the internal pterygoid muscle and the sagittal septum which relates the pharynx to the prevertebral fascia, contains the internal carotid artery and internal jugular vein.

The *retropharyngeal space* lies between the pharynx and prevertebral fascia and is continuous below with the retro-esophageal and mediastinal connective tissue. The cellular tissue behind the pharynx contains small, unimportant vessels, as well as several lymph nodes. These glands drain, to some extent, the nasal mucous membrane, the tonsils, the auditory tube region and the middle ear. They may become inflamed acutely with abscess formation, especially in the young. Acute pyogenic suppuration must not be confused with tuberculous retropharyngeal abscess, which arises from caries of the bodies of the cervical vertebrae and rarely breaks through the prevertebral fascia (Fig. 152). Pyogenic abscesses bulge into the pharynx, where they may be seen and palpated readily, and may be opened without fear of injury to the great vessels, which lie far to the lateral side. Ex-

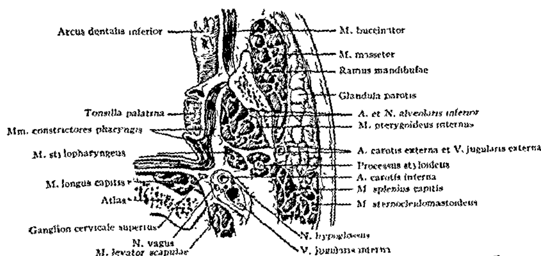


Fig. 151. Cross section through the middle of the tonsil to show the relations about the peripharyngeal spaces.

PART II

The Neck



PLATYSMA AND RELATED MUSCLES OF FACIAL EXPRESSION

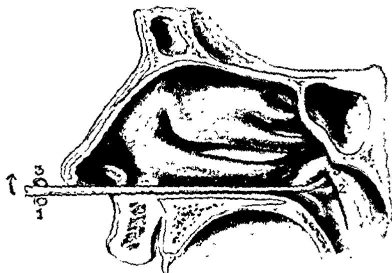


Fig. 153. CATHETERIZATION OF THE RIGHT AUDITORY (EUSTACHIAN) TUBE.

inate in the maxillary antrum, on the middle turbinate or on the posterior portion of the nasal septum. Polyps usually undergo cystic degeneration before attaining any considerable size. In the rhinoscopic mirror a polyp is seen as a bluish-white tumor which may fill the nasopharynx. It usually is removed with a nasal snare.

Primary sarcoma may occur in the nasopharynx at any age, and usually arises on the posterosuperior wall. Its rapid growth early leads to nasal obstruction.

Inflation of the Tympanic Cavity. The tympanic cavity may be inflated through the pharyngeal orifice of the auditory tube by means of a eustachian catheter (Fig. 153). This instrument is passed backward along the floor of the inferior meatus until its down-turned beak reaches the posterior wall of the nasopharynx. The catheter is rotated laterally through a right angle until its point is lodged in the pharyngeal recess. It is then withdrawn slowly until the point is felt to catch on the tubal eminence. Partial withdrawal and slight upward rotation of the beak then conduct it past the obstruction. The instrument, when directed laterally again, enters the orifice of the auditory tube.

General Considerations; Fasciae of the Neck

The neck provides passage for the many structures communicating between the head and trunk, and permits a wide range of movements of the head. The great number and variety of surgical conditions which occur in this region make it one of considerable practical interest and importance.

BOUNDARIES OF THE NECK. The superior boundary of the neck is the line of the inferior margin of the body of the mandible, continued from the angle of the jaw through the mastoid process joining the *superior* nuchal line. The *inferior* boundary is marked by the suprasternal notch, the superior margin of the clavicle, and a line drawn from the acromioclavicular joint to the spinous process of the seventh cervical vertebra (vertebra prominens).

SURFACE ANATOMY. The surface anatomy of the neck presents marked age, sex and individual variations. In children and women the contour is well rounded; in men the landmarks are prominent. The most important single landmark is the *sternocleidomastoid muscle*, which forms a broad relief between the anterior and lateral regions. In the midanterior region, particularly in men, the *thyroid cartilage* (*Adam's apple*) projects prominently (Figs. 155, 156). About 2.5 cm. above the margin of the thyroid cartilage lies the body of the *hyoid bone*, which, because of its mobility,

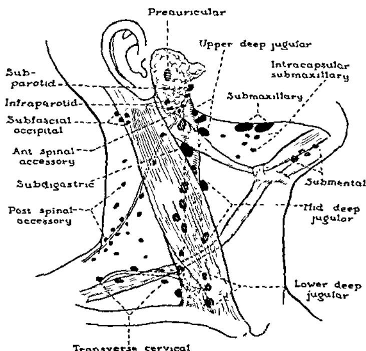


Fig. 154. SURFACE ANATOMY OF THE LATERAL REGION OF THE NECK, SHOWING THE DISTRIBUTION OF THE SUPERFICIAL AND DEEP CERVICAL LYMPH NODES.

A radical neck dissection should remove all the illustrated nodes except for the preauricular node. (From Beahrs, Gossel and Hollinshead: Am. J. Surg., 90: 490–516, 1955.)

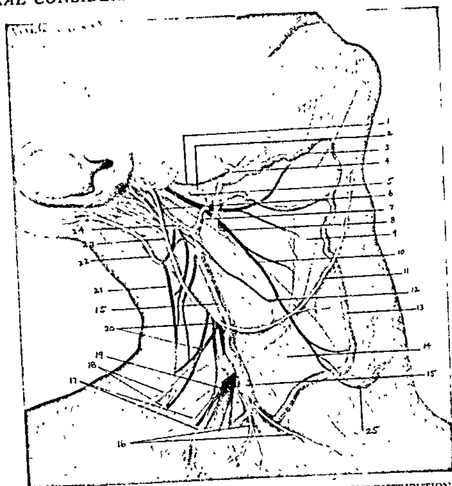


Fig. 156. SURFACE ANATOMY OF THE LATERAL REGION OF THE NECK AND THE DISTRIBUTION OF THE SUPERFICIAL VEINS AND NERVES.

1, Ramus marginalis mandibulae n facialis; 2, V. facialis posterior; 3, V. submentalis; 4, V. facialis anterior; 5, N. hypoglossus; 6, V. jugularis externa; 7, V. facialis communis; 8, V. jugularis interna, 9, M. omohyoideus; 10, ramus descendens n. hypoglossi, 11, N. cutaneus colli; 12, N. ansa hypoglossi; 13, V. jugularis anterior; 14, M. sternocleidomastoideus; 15, V. jugularis externa; 16, Nn. supraclaviculares anteriores; 17, Nn supraclaviculares medii; 18, Nn. supraclaviculares posteriores; 19, plexus brachialis; 20, trunks of supraclavicular nerves; 21, ramus externus nervi accessorii; 22, N. occipitalis minor; 23, N. auricularis magnus; 24, N. cervicalis III; 25, arcus venosus jugularis.

separated from the investing or enveloping layer of deep cervical fascia by the thin sheet of *platysma* muscle extending over the front of the neck (Frontispiece, Part II). Inferiorly, this muscle arises from the deep fascia of the pectoral region and from the clavicle; superiorly, it is attached to the mandible and extends to and blends with some of the muscles of the face. Closure of lacerations and operative incisions require careful approximation of the skin-platysma layer to avoid unsightly scars.

The DEEP FASCIA comprises an investing layer, with prevertebral and pretracheal divisions; these invest and support the muscles, pharynx, trachea, esophagus, lymph nodes, large vessels and nerves (Figs. 154 to 157; also Figs. 159 and 185). A complete envelope for all the cervical structures in the neck, save the platysma and the superficial vessels and nerves, is formed by the *investing layer of deep cervical fascia* (Fig. 157). It is attached above to the inferior margin of the mandible, and behind the angle of the jaw is carried up to enclose the parotid gland and attach to the zygomatic arch, mastoid process, superior nuchal line and external occipital protuberance. Posteriorly, this investing layer is attached over the spinous processes of the cervical vertebrae, and it, lamellae sheathe the trapezius muscle. At the anterior margin of the trapezius and over the supraclavicular triangle it appears as a single layer, dividing at the posterior edge of the sternocleidomastoid muscle, which it sheathes. Over the front of the neck superiorly, the fascia

must be steadied on both sides to render it palpable. The greater horn of the hyoid bone lies about midway between the mastoid process and the thyroid prominence. Just inferior to the thyroid prominence, the arch of the *cricoid cartilage* may be felt. Pressure at the anterior margin of the sternocleidomastoid muscle at the level of the cricoid cartilage compresses the common carotid artery against the anterior tuberosity of the transverse process of the sixth cervical vertebra. This palpable process is the *carotid tubercle* (of Chassaignac), and is the landmark in ligation of the common carotid artery. The anterior edge of the *trapezius muscle* may be traced from its origin along the superior nuchal line down the lateral region of the neck to its insertion on the clavicle. The prominent *spinous process* of the *seventh cervical vertebra* is an important landmark in the inferior portion of the nuchal furrow.

Topographic Division of the Neck. The neck may be divided topographically into three general regions: anterior, lateral and posterior. The *anterior* region comprises the structures between the sternocleidomastoid muscles, and is divided into suprahyoid and infrahyoid areas. The suprahyoid area has two subdivisions: submental and submaxillary. The infrahyoid area has several subdivisions: superficial infrahyoid, laryngotracheal, thyroid, cervical esophageal, and prevertebral. The *lateral* region is differentiated into the sternocleidomastoid (carotid) and the supraclavicular areas. To these general divisions is added the region of the root of the neck, the *thoracocervical* boundary between the neck and chest.

Divisions of Cervical Fascia and Fascial Spaces. The fasciae of the neck are superficial and deep (Fig. 156). The superficial fascia, carrying the superficial vessels and nerves, is

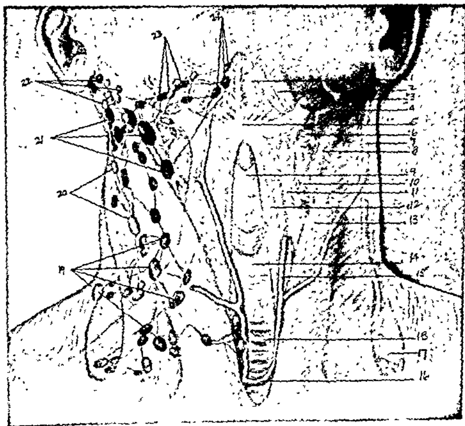


Fig. 155. SURFACE ANATOMY OF THE NECK AND DISTRIBUTION OF THE SUPERFICIAL AND DEEP CERVICAL LYMPH NODES.

1, M. mylohyoideus; 2, M. digastricus (venter anterior); 3, V. facialis communis; 4, M. digastricus (venter posterior); 5, os hyoideum; 6, V. lingualis; 7, V. jugularis externa; 8, V. jugularis interna, 9, cartilago thyreoidea; 10, V. thyreoidea superior; 11, M. omohyoideus (venter superior); 12, M. sternohyoideus; 13, M. sternocleidomastoideus; 14, isthmus glandulae thyreoideae; 15, V. jugularis anterior; 16, arcus venosus juguli; 17, M. omohyoideus (venter posterior); 18, trachea; 19, lymphoglandulae cervicales profundae inferiores; 20, lymphoglandulae cervicales superficiales; 21, lymphoglandulae cervicales profundae superiores; 22, lymphoglandulae parotideae; 23, lymphoglandulae submaxillares; 24, lymphoglandulae submentales.

forms the floor of the supraclavicular triangle, where it overlies the cervical and the subclavian vessels. These structures, on leaving the supraclavicular area, invaginate the prevertebral fascia and thus carry with them a fascial tubular prolongation known as the axillary sheath. Thus a collection of fluid under the prevertebral fascia may extend down this fascial tube along the axillary vessels and appear as a swelling on the lateral wall of the axilla along the course of the artery. It may appear as far down as the elbow. Superficial branches of the cervical plexus pierce the prevertebral layer, but the phrenic nerve remains deep to it (p. 202). Pus from tuberculosis of the cervical vertebrae lies behind the fascia, and may bulge into the posterior wall of the pharynx (retropharyngeal abscess). Owing to the strength of the fascia, perforation does not occur, and the pus usually passes downward and laterally to escape behind the sternocleidomastoid muscle into the supraclavicular triangle, where the fascial layer is weaker. Here it can be evacuated through an incision behind the muscle with retraction forward of the carotid sheath. Occasionally pus may pass downward behind the fascia into the posterior mediastinum.

The *pretracheal* or *middle layer of cervical fascia* is derived from the enveloping layer deep to the sternocleidomastoid muscle (Fig. 157). It lies in front of the laryngotracheal tube and the infrahyoid muscles and descends behind the enveloping layer into the root of the neck and mediastinum to blend with the covering of the aorta and pericardium. It is much more delicate than the prevertebral fascia, and its densest and most differentiated portion covers the area below the hyoid bone between the omohyoid muscles, the sternal halves of the clavicles, and the suprasternal notch. Laterally, it forms the carotid sheath. The anterior fascial layer of the pretracheal division sheathes the omohyoid and sternohyoid muscles; the posterior layer sheathes the sternothyroid muscle. In the root of the neck, fibrous expansions are thrown over the large vascular trunks, tending to hold them open, so that a sectioned vessel in the region will not close readily, and entrance of air (air embolus) may occur with a fatal result.

Three SPACES are delimited by these fasciae.

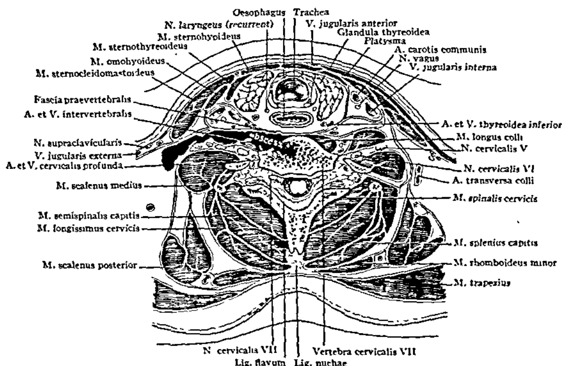


Fig. 158. CROSS SECTION THROUGH THE NECK AT THE LEVEL OF THE SEVENTH CERVICAL VERTEBRA TO SHOW TUBERCULOUS EROSION OF THE VERTEBRAL BODY AND THE LATERAL EXTENSION OF THE RESULTING TUBERCULOUS ABSCESS INTO THE SUPRACLAVICULAR REGION BEHIND THE PREVERTEBRAL FASCIA.

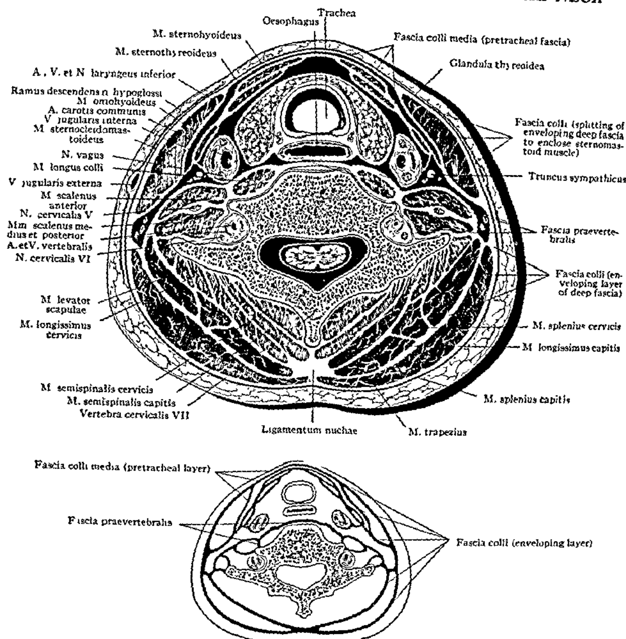


Fig. 157. CROSS SECTION THROUGH THE NECK AT THE LEVEL OF THE SEVENTH CERVICAL VERTEBRA TO SHOW THE LAYERS OF DEEP CERVICAL FASCIA.

Inset delineates the fascial layers without reference to the structures they enclose.

appears again as a single layer to meet the corresponding layer of the opposite side in the midline. It is attached to the hyoid bone, and below this level it splits to form a superficial and a deep layer. These layers are applied to the anterior and posterior borders of the sternum (p. 176). Between them lie the sternal heads of the sternocleidomastoid muscles and the anterior jugular veins in their course toward the external jugular veins. Between the angle of the jaw and the greater horn of the hyoid bone the enveloping layer fuses with the fascial covering of the posterior belly of the digastric muscle. Similar fusion takes place between the enveloping fascia and that covering the anterior belly of the digastric muscle. Thus the submaxillary and submental areas, to a great extent, are shut off from one another and from the other regions of the neck.

The *prevertebral fascia* is the more posterior septum derived from the enveloping layer (Fig. 157). It extends over the prevertebral musculature across the neck behind the pharyngo-esophageal tube. It lies behind the great vessels of the neck and covers the muscles on which they lie. The prevertebral fascia

forms the floor of the supraclavicular triangle, where it overlies the cervical and the subclavian vessels. These structures, on leaving the supraclavicular area, invaginate the prevertebral fascia and thus carry with them a fascial tubular prolongation known as the axillary sheath. Thus a collection of fluid under the prevertebral fascia may extend down this fascial tube along the axillary vessels and appear as a swelling on the lateral wall of the axilla along the course of the artery. It may appear as far down as the elbow. Superficial branches of the cervical plexus pierce the prevertebral layer, but the phrenic nerve remains deep to it (p. 202). Pus from tuberculosis of the cervical vertebrae lies behind the fascia, and may bulge into the posterior wall of the pharynx (retropharyngeal abscess). Owing to the strength of the fascia, perforation does not occur, and the pus usually passes downward and laterally to escape behind the sternocleidomastoid muscle into the supraclavicular triangle, where the fascial layer is weaker. Here it can be evacuated through an incision behind the muscle with retraction forward of the carotid sheath. Occasionally pus may pass downward behind the fascia into the posterior mediastinum.

The *pretracheal* or *middle layer of cervical fascia* is derived from the enveloping layer deep to the sternocleidomastoid muscle (Fig. 157). It lies in front of the laryngotracheal tube and the infrahyoid muscles and descends behind the enveloping layer into the root of the neck and mediastinum to blend with the covering of the aorta and pericardium. It is much more delicate than the prevertebral fascia, and its densest and most differentiated portion covers the area below the hyoid bone between the omohyoid muscles, the sternal halves of the clavicles, and the suprasternal notch. Laterally, it forms the carotid sheath. The anterior fascial layer of the pretracheal division sheathes the omohyoid and sternohyoid muscles; the posterior layer sheathes the sternothyroid muscle. In the root of the neck, fibrous expansions are thrown over the large vascular trunks, tending to hold them open, so that a sectioned vessel in the region will not close readily, and entrance of air (air embolus) may occur with a fatal result.

Three SPACES are delimited by these fasciae.

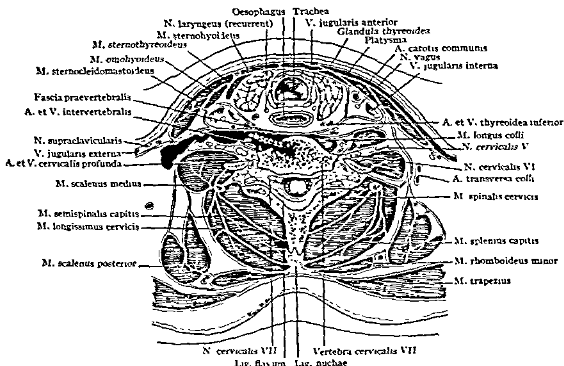


Fig. 158. CROSS SECTION THROUGH THE NECK AT THE LEVEL OF THE SEVENTH CERVICAL VERTEBRA TO SHOW TUBERCULOUS EROSION OF THE VERTEBRAL BODY AND THE LATERAL EXTENSION OF THE RESULTING TUBERCULOUS ABSCESS INTO THE SUPRACLAVICULAR REGION BEHIND THE PREVERTEBRAL FASCIA.

The *visceral space*, lying between the pretracheal and prevertebral fasciae, contains the laryngotracheal tube, lower pharynx, cervical esophagus, thyroid gland and great vessels. These structures are surrounded by areolar connective tissue which is sufficiently lax to permit great distention. Fluid collections in this compartment may spread behind the clavicle into the mediastinum, or may follow the subclavian vessels into the axillary space. Migrating abscesses within this space may burrow laterally into the posterior cervical triangles, or upward through the submaxillary areas into the retromandibular spaces. The *suprahyoid space* lies between the enveloping fascia and the fascial covering of the mylohyoid muscles. Fluids may collect in either the submaxillary or submental divisions of this space and invade the visceral compartment. The *prevertebral space* lies on the vertebral bodies and muscles behind the prevertebral fascia (Fig. 158). The products of caries of the cervical vertebrae invade this musculofibro-osseous compartment, and either migrate laterally, or burrow along the cervical column through the thoracic inlet and into the posterior mediastinum.

CHAPTER 7

Anterior Regions of the Neck

Suprahyoid Areas

The suprahyoid region has three divisions: a median submental and two lateral submaxillary (Fig. 159). For purposes of topography, the submaxillary areas are understood to extend to the anterior margins of the sternocleidomastoid muscles.

MEDIAN SUPRAHYOID OR SUBMENTAL REGION

LOCATION AND BOUNDARIES. The submental region is a triangle, having as its base the body of the hyoid bone, as its apex the symphysis of the mandible, and as its lateral margins the anterior bellies of the digastric muscles. Its floor consists of the mylohyoid muscles, which separate it from the sublingual compartment. The roof or outer covering is the investing layer of the deep cervical fascia.

CONTENTS. The submental group of pea-sized *lymph nodes* receives afferents from the chin, central portion of the lower lip, centrally placed teeth, gums, floor of the mouth, and tip of the tongue (Fig. 155). *Abscess* of these glands produces a swelling which bulges downward below the chin, but is hindered from rising into the mouth by the mylohyoid muscles.

Ranulas and other tumors in the sublingual space (p. 150) usually present in the floor of the mouth, but may bulge downward into the submental space. The efferents of the submental glands pass to the submaxillary group. That portion of the thyroglossal duct (p. 151) which traverses the region may give rise to a *cyst* which presents in the median line above the hyoid bone.

SURGICAL ACCESS. Access to the contents of the submental region is obtained by a horizontal incision just above the hyoid bone (Fig. 160). After the investing layer of deep fascia has been penetrated the digastric muscles and mylohyoid floor are guides to lateral and deeper structures. Wide incision can be made because there are no important contents. Because of the edema of the overlying and surrounding structures, abscesses which seem superficial are found to be deep. Infection in the adjoining submaxillary areas may be reached by blunt dissection and drained into the submental incision. A sublingual cyst is accessible through a horizontal incision (Fig. 160, *E*), splitting the mylohyoid raphe.

LATERAL SUPRAHYOID OR SUBMAXILLARY REGION

DEFINITION AND BOUNDARIES. The lateral *suprahyoid or submaxillary region is comprised essentially of the digastric triangle and its submaxillary contents; for topographic purposes, the region extends *laterally* to the sternocleidomastoid muscle (Fig. 159). The *inferior* boundary is a line from the point of attachment of the digastric tendons along the body of the hyoid bone to the sternocleidomastoid muscle; the *superior* boundary is the inferior margin of the mandible, projected to the sternocleidomastoid muscle; and the *anterior* limit is the anterior belly of the digastric muscle.

The *outer wall* or *roof* of the area is the investing layer of the deep cervical fascia connecting the inferior margin of the mandible and the hyoid bone. Through it are visible the digastric bellies and the submaxillary gland. The *deep wall* or *floor* is formed by the mylohyoid muscle, the posterior part of the hyoglossal muscle, and the lateral surface of the middle constrictor muscle of the pharynx. Between the posterior border of the mylohyoid and the superjacent hyoglossus is a cleft which forms a communication with the sublingual region (p. 147).

The trimuscular floor of the suprahyoid region may be divided into three areas: a pre-

The *visceral space*, lying between the pretracheal and prevertebral fasciae, contains the laryngotracheal tube, lower pharynx, cervical esophagus, thyroid gland and great vessels. These structures are surrounded by areolar connective tissue which is sufficiently lax to permit great distention. Fluid collections in this compartment may spread behind the clavicle into the mediastinum, or may follow the subclavian vessels into the axillary space. Migrating abscesses within this space may burrow laterally into the posterior cervical triangles, or upward through the submaxillary areas into the retromandibular spaces. The *suprahyoid space* lies between the enveloping fascia and the fascial covering of the mylohyoid muscles. Fluids may collect in either the submaxillary or submental divisions of this space and invade the visceral compartment. The *prevertebral space* lies on the vertebral bodies and muscles behind the prevertebral fascia (Fig. 158). The products of caries of the cervical vertebrae invade this musculofibro-osseous compartment, and either migrate laterally, or burrow along the cervical column through the thoracic inlet and into the posterior mediastinum.

from the external carotid artery on a level with the great horn of the hyoid bone, and enters this compartment under the stylohyoid muscle and the posterior belly of the digastric muscle. It continues upward and forward in a groove in the posterior surface of the gland, emerges from the deep fascia, winds around the inferior border of the body of the mandible, and reaches the face at the anterior margin of the masseter muscle. In contrast to the deep-lying artery are the superficially coursing *facial veins*. These run over the submaxillary gland just beneath the fascial covering of the space and empty into the common facial (thyro-facial-lingual) vein, which drains into the external jugular. The *lingual artery* is the only other large arterial trunk in the region. From its external carotid origin it runs a short stretch in the lateral suprahyoid region above the hyoid bone and extends deep to the posterior margin of the hyoglossal muscle. It courses forward on the mesial aspect of this muscle, into the sublingual compartment (Fig. 159).

Three to six *lymph nodes* are disposed about the submaxillary salivary gland; the greater number lie immediately under the deep cervical fascia, and the remainder between the gland and the mylohyoid muscle. They are regional nodes for lymph vessels from the nose, lips and anterior and lateral portions of the tongue. Their efferents lead into the deep cervical lymph nodes in the sternocleidomastoid region. The numerous infections in the regions tributary to the glands explain the great frequency of suprahyoid abscess formation. These nodes are involved secondarily in cancer within the drainage territory, and are closely attached to, and sometimes incorporated in, the substance of the submaxillary gland; their removal necessitates clearing the compartment of its glandular content (Fig. 154).

The *hypoglossal nerve* enters the submaxillary space between the hyoglossal muscle and the posterior belly of the digastric muscle and runs through the greater portion of the suprahyoid space before entering the sublingual compartment through the cleft between the hyoglossal and mylohyoid muscles. The *lingual nerve* lies at a much higher level on the lateral surface of the hyoglossal muscle (Fig. 144). It supplies a branch to the submaxillary gland which must be severed in suprahyoid dissection before the gland can be mobilized.

Surgical Considerations

Placement of Incisions in the Neck. An incision crossing the normal lines of the skin, particularly in a region of constant motion, such as the neck, will almost certainly widen, become more prominent even to the point of

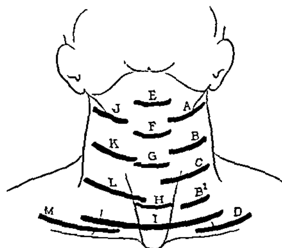


Fig. 160. PROPER PLACEMENT OF INCISIONS IN THE NECK PARALLELING THE NORMAL LINES AND CREASES OF THE SKIN.

A, For excision of congenital sinus—partial mobilization here and *lower segment at B*[1]; *B, for* excision of carotid tumor or branchial cleft cyst; C, for diverticulum of esophagus; *D*, for scalenotomy or phrenic nerve *interruption*; *E, for drainage* of submental abscess; *F*, for excision of thyroglossal cyst or sinus; *G*, for cricothyreotomy; *H*, for tracheotomy; *I*, for thyroidectomy; *J*, for drainage of cervical abscess at angle of jaw; *K*, for exposure of internal or external carotid arteries; *L*, for exposure of common carotid artery; *M*, for exposure of brachial plexus or subclavian artery. (From Holman: Surg., Gynec. & Obst., 78: 533-4, 1944.)

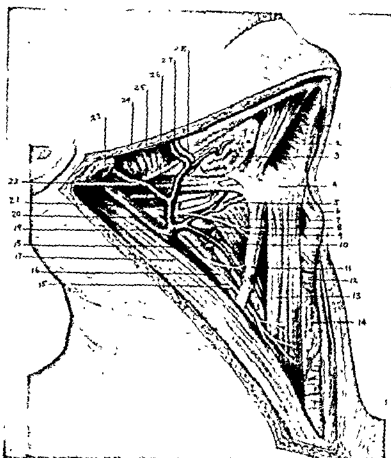


Fig. 159. RELATIONS BETWEEN THE SUBMAXILLARY, SUBMENTAL AND UPPER STERNOCLEIDOMASTOID REGIONS.

1, M. mylohyoideus; 2, M. digastricus (venter anterior); 3, glandula submaxillaris; 4, os hyoideum; 5, N. hypoglossus; 6, cartilago thyreoidea; 7, ramus thyreohyoideus n. hypoglossi; 8, N. laryngeus superior; 9, A. et V. laryngea superior; 10, A. et V. thyreoidea superior; 11, M. omohyoideus (venter superior); 12, cartilago cricoidea; 13, M. sternohyoideus; 14, isthmus glandulae thyreoideae; 15, N. ansa hypoglossi; 16, ramus descendens n. hypoglossi; 17, M. sternocleidomastoideus; 18, A. carotis communis; 19, V. jugularis interna; 20, A. et V. lingualis; 21, V. facialis communis; 22, V. facialis posterior; 23, glandula parotis; 24, M. masseter; 25, M. digastricus (venter posterior); 26, M. stylohyoideus; 27, V. facialis anterior; 28, A. maxillaris externa.

digastric, the floor of the submental area; an interdigastric, the floor of the submaxillary area; and a retrodigastric, extending to the margin of the sternocleidomastoid muscle. The retrodigastric area is the lowermost part of the parapharyngeal space, and its posterior extremity is separated from the contents of the parotid compartment by a septum.

CONTENTS. Incision through the deep fascia reveals the *submaxillary salivary gland*, which can be separated easily from the cellular tissue surrounding it. The gland may be retracted without injury to adjacent structures, an important fact in ligation of the lingual artery. The normal gland is about the size of a large almond, but it is enlarged by infection, malignancy or involvement of the lymph nodes about it. Malignancy may be primary; more commonly it is secondary, the extension of a tumor process from an adjacent structure, such as the tongue, floor of the mouth, jaw or lymph nodes. In malignancy the gland may become fixed to the mandible.

The inferior border of the submaxillary salivary gland often extends below the great horn of the hyoid bone. A portion of it may overlie and extend beyond the posterior digastric belly, reaching almost to the sternocleidomastoid muscle. A deep prolongation penetrates the sublingual region through the cleft between the mylohyoid and hyoglossal muscles. This prolongation and its duct (of Wharton) have immediate relations with the sublingual gland. The posterior extremity of the submaxillary gland presents intimate and important surgical relations with the parotid gland, external maxillary artery, and the thyroid, hypoglossal and facial trunks of the common facial vein.

The *external maxillary (facial) artery* arises

keloid formation, and be unsightly. Occasionally, in dealing with long sections of structures traversing the neck up and down, such as lymphatic chains, vertical incisions are better. Holman, however, has reaffirmed that in the great majority of cases transverse incisions are entirely adequate (Fig. 160), leave a much better cosmetic result, which is much appreciated by women, and show a regard for the important details making up the art of surgery.

SUBMAXILLARY ABSCESS. Submaxillary abscesses arise from lymphatic involvement incident to infections in the tributary areas. The infection may settle in the lymph nodes as adenitis, or manifest itself as lymphangitis or cellulitis. The buccal cavity, teeth, tongue, gums and pharynx drain directly to the space, and the afferent vessels also drain the upper forehead, inner eyebrow and anterior face.

One of the commonest sources of infection is an alveolar abscess which gravitates into the compartment from a carious tooth. The acute and exceedingly grave infection known as *Ludwig's angina* begins in the sublingual region and rapidly involves the submaxillary region, since the cellular tissue is in continuity (Fig. 116). This fulminating cellulitis may spread rapidly into the neck, up on the face or into the pharynx, and often proves fatal. It calls for the immediate use of antibiotics. If an abscess forms, which is not common with adequate therapy, incision and drainage should be carried out through a transverse incision made at the dependent point of the submaxillary triangle.

Figure 161 shows the excellent modification by Brown and McDowell of the early Crile operation. The lymph node-bearing tissue is removed in one block. The neck scar is relatively inconspicuous.

A deformity of the lower lip would be the result of cutting the mandibular branch of the seventh nerve. The nerve should be saved unless the neighboring submaxillary lymph nodes are involved by metastasis (Beahrs). A method designed to spare this important branch is described on page 137 (see Figs. 130, 131).

Infrahyoid Areas

The infrahyoid region is described as the mesial triangle (trigonum) of the neck. It has as its base the hyoid bone, and as its sides the mesial borders of the sternocleidomastoid muscles. It is made up of several subregions: superficial infrahyoid; those of the thyroid gland, laryngotracheal tube and cervical esophagus; and prevertebral region.

SUPERFICIAL INFRAHYOID REGION

DEFINITION AND BOUNDARIES. The superficial infrahyoid region extends from the hyoid bone to the suprasternal notch, and embraces the superficial structures anterior to the thyroid gland and the laryngotracheal tube.

SURFACE ANATOMY. When the head is thrown back, the infrahyoid region is well outlined (Fig. 162). The laryngotracheal tube and the thyroid gland form a median bulge. On each side, mesial to the sternocleidomastoid muscle, the carotid groove can be seen and palpated. In the depth of each gutter the pulsations of the carotid artery can be felt and even seen. With the head flexed, landmarks are palpated more readily. The bulge of the thyroid cartilage is felt below the hyoid bone; and below it, the transverse bulge of the cricoid cartilage. The interval between the two cartilages is occupied by the cricothyroid membrane.

SUPERFICIAL STRUCTURES. The veins in the region are small and irregularly placed, and empty, for the most part, into the external jugular vein. The *anterior jugular veins* are important in any transverse incision in this region. They arise from the superficial submental veins by anastomosis with the facial veins, descend paramedially to within a few centimeters of the suprasternal fossa, engage under the sternocleidomastoid muscles, parallel the upper margins of the clavicles, and empty into the termination of the external jugulars. In the superior portion of their course they lie superficial to the platysma muscle; more inferiorly, they are covered by it; near the sternum they are held intimately within the meshes of, or deep to, the enveloping fascia. This arrangement makes it possible in a transverse incision in the lower neck to reflect the skin and the platysma layer upward and downward without involving these veins. A thyroglossal duct sinus or fistula (p. 197) sometimes presents in this region.

ENVELOPING FASCIA AND THE SUPRASTERNAL FOSSA. Over all the region the *enveloping fascia* lies immediately subjacent to the skin-platysma layer, covering the areas as with a veil. The fascia divides at the mesial border of the sterno-

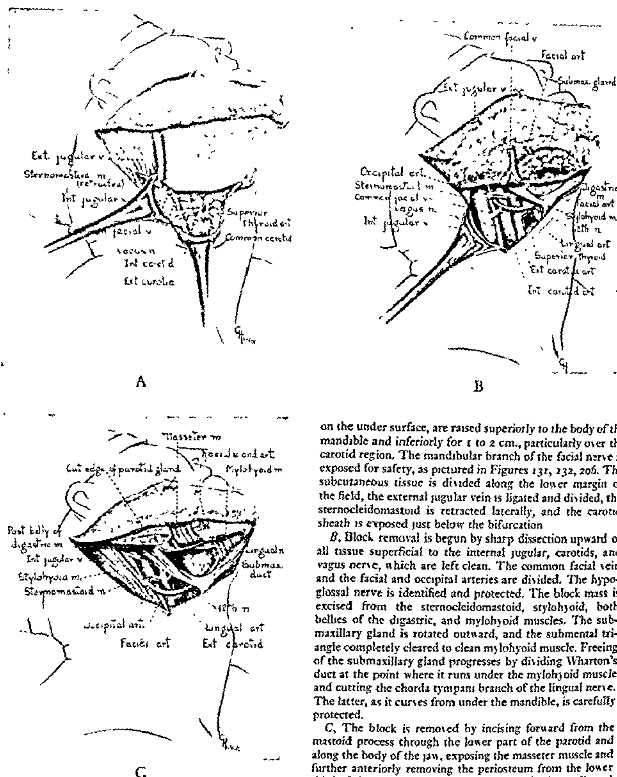


Fig. 161. UPPER CERVICAL (SUPRAHYOID) LYMPH NODE DISSECTION.

A, The incision (Kocher) curves across the neck from one mastoid process to the other, runs 3 cm below the angle of the jaw, and crosses the midline just above the hyoid bone. The skin flaps, which are thin enough to show hair follicles on the under surface, are raised superiorly to the body of the mandible and inferiorly for 1 to 2 cm., particularly over the carotid region. The mandibular branch of the facial nerve is exposed for safety, as pictured in Figures 131, 132, 206. The subcutaneous tissue is divided along the lower margin of the field, the external jugular vein is ligated and divided, the sternocleidomastoid is retracted laterally, and the carotid sheath is exposed just below the bifurcation

B, Block removal is begun by sharp dissection upward of all tissue superficial to the internal jugular, carotids, and vagus nerve, which are left clean. The common facial vein and the facial and occipital arteries are divided. The hypoglossal nerve is identified and protected. The block mass is excised from the sternocleidomastoid, stylohyoid, both bellies of the digastric, and mylohyoid muscles. The submaxillary gland is rotated outward, and the submental triangle completely cleared to clean mylohyoid muscle. Freeing of the submaxillary gland progresses by dividing Wharton's duct at the point where it runs under the mylohyoid muscle and cutting the chorda tympani branch of the lingual nerve. The latter, as it curves from under the mandible, is carefully protected.

C, The block is removed by incising forward from the mastoid process through the lower part of the parotid and along the body of the jaw, exposing the masseter muscle and further anteriorly removing the periosteum from the lower third of the mandible. The facial artery and vein are ligated and divided where they are crossed. If desired, the block may be left attached in the midline until a similar dissection is completed on the opposite side. Skin closure is completed with a small drain brought out at the lateral angles and the midline, followed by a snug compression dressing. (From Brown and McDowell: Surg., Gynec. & Obst., 79: 115-24, 1944.)

cal or pretracheal fascia unite in one layer directly overlying the trachea and thyroid gland (Fig. 157). This layer is fused to the overlying enveloping layer to form the aponeurotic *linea alba of the neck*, through which access to the thyroid gland is gained.

Spreading aside of the musculo-aponeurotic layers of the infrahyoid region reveals the laryngotracheal tube, thyroid and esophagus in their common fascial casing, the *visceral sheath.* These structures are designated the "visceral mass." This is attached to the vertebral column by sagittal septa.

LARYNGOTRACHEAL REGION

The laryngotracheal tube or median air passage is made up of the larynx and the cervical trachea.

LARYNX. The larynx is a series of cartilages adapted for phonation. The thyroid and cricoid cartilages constitute the principal part of its framework, and the epiglottis guards its entrance (Fig. 163). There are also three sets of paired cartilages: the arytenoids, corniculates and cuneiforms. The arytenoids furnish attachment to the intrinsic muscles of the larynx which govern the tension of the vocal cords. The whole larynx is capable of a considerable range of mobility. It moves up and down with each effort of swallowing, and laterally with passive movement produced by palpation or by the pressure of a neighboring mass.

HYOID BONE AND CARTILAGES OF THE LARYNX. The *hyoid* bone, the chief support for the true laryngotracheal tube, is elevated, depressed and moved forward in speech, mastication and swallowing. The anterior aspect of the bone is superficial and accessible to palpation (Fig. 163). With the chin elevated, it may be grasped between the thumb and forefinger and moved from side to side. It forms a stable, yet flexible, fixation center, slung above from the styloid process of the temporal bone and from the mandible and tongue, and secured below by its attachment to the larynx. The genioglossal and hyoglossal muscles attach the hyoid bone to the tongue, and the mylohyoid, geniohyoid and digastric muscles connect it with the lower jaw. It supports the larynx by means of the thyrohyoid muscles and thyrohyoid membrane. It is fixed to the sternum by the sternohyoid muscles, and to the scapulae by the omohyoid muscles (Figs. 159, 162). Its mobility, pliability and protection explain the infrequency of fracture.

The leaflike *epiglottic cartilage* lies dorsal to the root of the tongue and ventral to the opening into the larynx (Figs. 163, 164). It is attached by the thyro-epiglottic ligament to the body of the thyroid cartilage just above the vocal cords, and is connected to the base of the tongue by the glosso-epiglottic folds. During respiration the epiglottis is semivertical. In the act of swallowing (deglutition), the epiglottis does not fall, valvelike, over the laryngeal opening, but maintains its upright position. Solid food is swept beyond it by the base of the tongue into the grasp of the constrictor musculature of the pharynx. The pharyngeal muscles direct the food into the esophagus. Liquids are

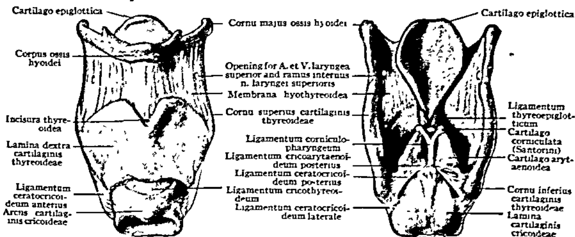


Fig. 163. ANTERIOR AND POSTERIOR VIEWS OF THE LARYNX, ITS CONNECTING LIGAMENTS, AND THE HYOID BONE.

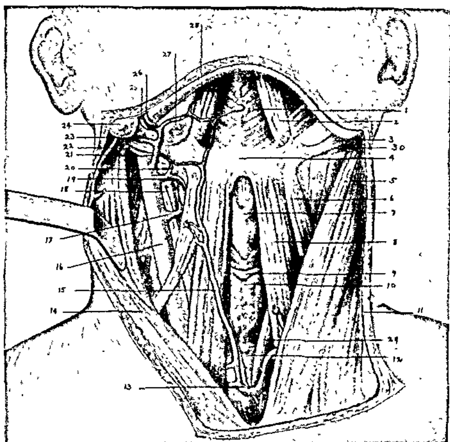


Fig. 162. STRUCTURES IN THE SUPRAHYOID AND INFRAHYOID REGIONS.

1, M. mylohyoideus; 2, M. digastricus (venter anterior); 3, M. stylohyoideus; 4, os hyoideum; 5, M. sternocleidomastoideus; 6, M. omohyoideus; 7, cartilago thyreoidea; 8, M. sternohyoideus; 9, cartilago cricoidea; 10, isthmus glandulae thyreoideae; 11, platysma; 12, trachea; 13, arcus venosus juguli; 14, M. sternocleidomastoideus; 15, V. jugularis anterior; 16, V. jugularis interna; 17, V. thyreoidea superior; 18, ramus descendens n. hypoglossi; 19, V. laryngea superior; 20, V. lingualis; 21, V. facialis communis; 22, V. jugularis externa; 23, V. facialis posterior; 24, glandula parotis; 25, V. facialis anterior; 26, A. maxillaris externa (facial); 27, glandula submaxillaris; 28, V. submentalis; 29, M. sternothyreoideus; 30, M. digastricus (venter posterior).

cleidomastoid muscles to enclose them, forming their sheaths. Lower down in the neck the enveloping fascia splits into two layers, an anterior layer attached to the anterior superior margin of the manubrium, and a posterior layer attached to the posterior superior margin. Between them is the *suprasternal fossa* (of Burns, Gruber), which has premanubrial and retromanubrial culs-de-sac whose lateral projections insinuate themselves under the sternocleidomastoid muscles. The posterior wall of the space is reinforced by the deeper (pretracheal) fascia investing the infrahyoid muscles. The anterior jugular veins and their transverse anastomosis (arcus venosus juguli) traverse the space, which holds also suprasternal lymphatic glands and areolar tissue.

INFRAHYOID MUSCLES AND THEIR FASCIAL CONNECTIONS. Deep to the enveloping fascia are two muscle layers, enclosed within the pretracheal fascia. The superficial layer includes the omohyoid muscle laterally and the sternohyoid muscle mesially. Only the upper part of the *omohyoid* belongs to this region; its posterior belly traverses the lateral portion of the neck in its course to the scapula. The *sternohyoid* is entirely within the region. The triangular interval, formed by the divergence of the omohyoid and sternohyoid, is occupied by pretracheal fascia (Figs. 157, 162).

The deep layer consists of the sternothyroid and thyrohyoid muscles. The *sternothyroid* arises deep to the sternohyoid from the posterior surface of the sternum and inserts into the thyroid cartilage. The *thyrohyoid* continues the line of the sternothyroid, running from the thyroid cartilage to the great cornu of the hyoid bone. The sternothyroid muscles diverge upward. Within the interval thus formed the superficial and deep layers of the middle cervi-

lages, to the anterior angles of which the vocal cords are attached.

MEMBRANES OF THE LARYNX. The uniformly resistant *thyrohyoid membrane* suspends the larynx from the hyoid bone by extending from its posterosuperior margin to the upper margin of the thyroid cartilage (Fig. 163). The bursa between the superior portion of the membrane and the body of the hyoid bone may become inflamed and cystic. Posteriorly, the membrane is separated from the epiglottis by a wedge-shaped mass of fatty tissue which occupies the thyro-epiglottic space.

The *conus elasticus* (*cricothyroid membrane*)

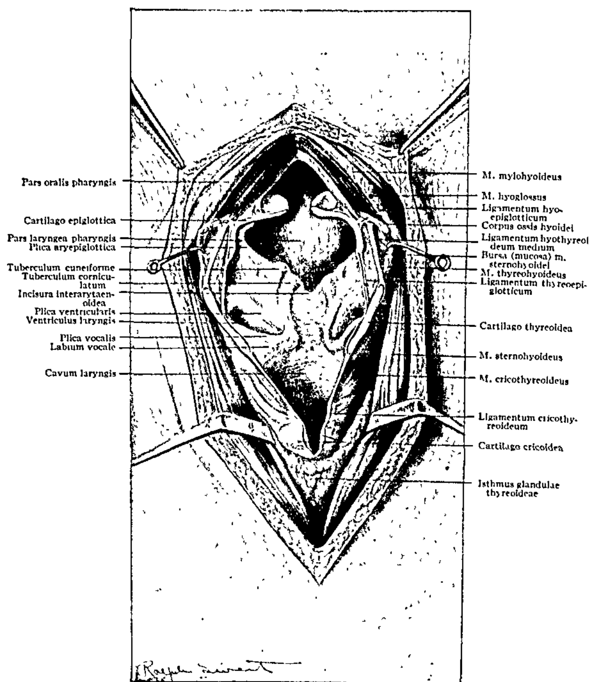


Fig. 165. FRONT VIEW OF A PARTIAL MIDSAGITTAL SECTION THROUGH THE PHARYNX, LARYNX AND UPPER TRACHEA.

The cricothyroid ligament is greatly elongated to show the interior of the subglottic area.

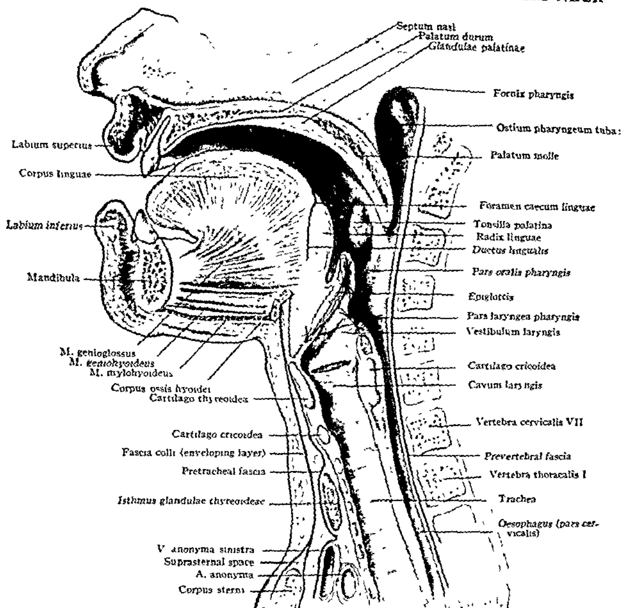


Fig. 164. SAGITTAL SECTION THROUGH THE UPPER AIR PASSAGES, PHARYNX AND ESOPHAGUS.

diverted around the epiglottis into the piriform sinuses of the pharynx and thence into the esophagus.

The *thyroid cartilage*, because of its strength and power of resistance, affords valuable protection to the structures in the larynx, most important of which are the vocal cords. Its two quadrangular lateral plates (laminae) unite in the midline of the neck to form a prominent angle, the Adam's apple, which is palpable and is the principal landmark of the larynx (Fig. 164). During early adult years the thyroid cartilage is hyaline, but, as a rule, by the twentieth year it begins to ossify. Ossification may progress to such a state that in older people the cartilage sometimes fractures on lateral compression of the two wings, or compression backward against the vertebral column, as in strangling or hanging. Injury to this cartilage may be serious because of subsequent edema of the laryngeal mucous membrane, with impairment of respiration.

The *cricoid cartilage* is the palpable landmark indicating the beginning of the trachea, and corresponding in level to the superior border of the esophagus. It is a modified tracheal cartilage shaped like a signet ring with the seal placed posteriorly, and is adapted to support the larynx (Fig. 163). In front, its narrow arch is attached to the thyroid cartilage by the conus elasticus (cricothyroid membrane).

The upper angles of the signet part of the cricoid cartilage support the *arytenoid carti-*

MENT, extends from the laryngeal inlet to the level of the false vocal cords (plicae ventriculares (Figs. 165, 166). Its walls may be the seat of localized edema, infiltration, tumors and ulceration. Cancer rarely involves it, and, when it does, is secondary, extending from the base of the tongue, and pharynx. The two membranous folds known as the *false vocal cords* play no role in phonation. In laryngoscopic examination they appear as horizontal projections from the inner surfaces of the aryepiglottic folds (Fig. 167).

The GLOTTIS, or MIDDLE COMPARTMENT of the larynx, corresponds to the recess or ventricle between the true and false cords. It contains the arytenoid cartilages behind, which are separated by the interarytenoid notch. The mucosa uniting them is the posterior commissure, the seat of election of early tuberculosis of the larynx. The *true vocal cords* are contiguous at the anterior commissure and diverge behind, separated by the breadth of the posterior commissure. In the laryngoscopic mirror the cords appear as thin, brilliant bands, converging anteriorly. In contrast to the mucosa of the vestibule of the larynx, that of the true cords adheres so intimately that these cords rarely are the seat of edema. In acute or chronic inflammatory conditions the cords lose their brilliant color and take on reddish and violet colorations. They frequently are the seat of intrinsic carcinoma of the larynx.

The *rima glottidis* (*glottic slit*) is the fissure which separates the true vocal cords and the arytenoid cartilages (Fig. 167). The vocal or ligamentous glottis is in front, and the respira-

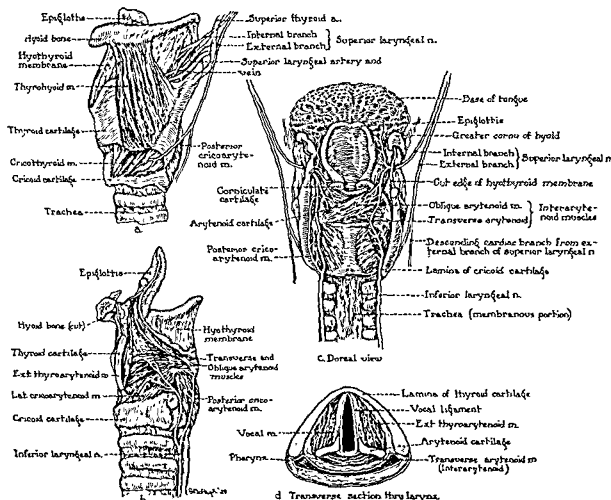


Fig. 168. DISSECTION OF THE LARYNX TO SHOW THE INTRINSIC LARYNGEAL MUSCLES AND THE DISTRIBUTION OF THE LARYNGEAL NERVES.

Note the muscular distribution of the internal branch of the superior laryngeal nerve. (Modified from Jackson, from Nordland: Surg., Gynec. & Obst., 51: 449-59, 1930.)

Radix linguae
Tonsilla palatina
Vestibulum laryngis
Vallecula epiglottica
Plica pharyngo-epiglottica
Labium vocale
Epiglottis
Pars intermembranacea rimae glottidis
Tuberculum cuneiforme (Wrisbergi)
Pars intercartilaginea rimae glottidis
Tuberculum corniculatum (Santorini)
Tunica mucosa pharyngis
Pars laryngea pharyngis
Incisura interarytaenoidea

Fig. 166. POSTERIOR PORTION OF THE TONGUE AND ITS RELATION TO THE ADITUS OF THE LARYNX. (After Sobotta.)

closes the interval between the cricoid and thyroid cartilages. Through it the easiest and most rapid laryngotomy can be performed for the urgent relief of suffocation (p. 186).

INTERIOR OF THE LARYNX, OR ENDOLARYNX. The cavity of the larynx is divided into three compartments by two paired folds of mucous membrane stretched anteroposteriorly across it. These folds project medially from the lateral walls and extend from the arytenoid cartilages to the thyroid cartilage below the attachment of the epiglottis (Figs. 164, 165). The superior folds are the false vocal cords, and the inferior the true ones. The compartments are the upper supraglottic area (vestibule); the middle, more constricted glottic area; and the broad, infraglottic area. The ENTRANCE (aditus) into the LARYNX is triangular (Fig. 166). The base of the triangle, directed forward, is formed by the epiglottis; its lateral boundaries are the aryepiglottic muscles in the aryepiglottic folds. On either side of the laryngeal opening is a pharyngeal recess, termed the *piriform sinus* (Fig. 167). This recess is likely to be the lodging place of foreign bodies entering the pharynx.

The VESTIBULE, OR SUPRAGLOTTIC COMPART-



Fig. 167. A MIRROR LARYNGOSCOPIC IMAGE WITH THE GLOTTIS OPEN.

MENT, extends from the laryngeal inlet to the level of the false vocal cords (plicae ventriculares (Figs. 165, 166). Its walls may be the seat of localized edema, infiltration, tumors and ulceration. Cancer rarely involves it, and, when it does, is secondary, extending from the base of the tongue, and pharynx. The two membranous folds known as the *false vocal cords* play no role in phonation. In laryngoscopic examination they appear as horizontal projections from the inner surfaces of the aryepiglottic folds (Fig. 167).

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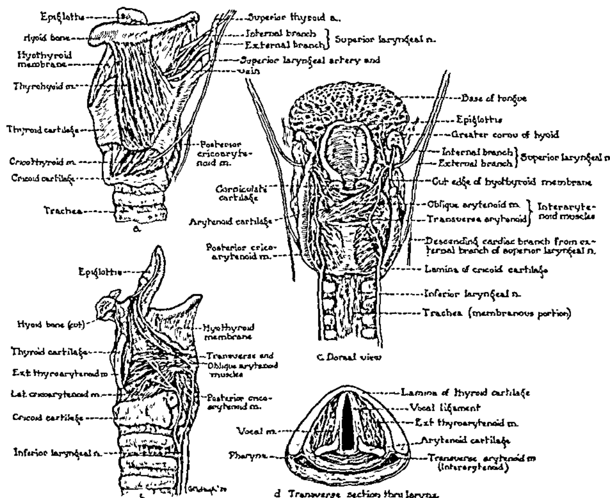


Fig. 168. DISSECTION OF THE LARYNX TO SHOW THE INTRINSIC LARYNGEAL MUSCLES AND THE DISTRIBUTION OF THE LARYNGEAL NERVES.

Note the muscular distribution of the internal branch of the superior laryngeal nerve. (Modified from Jackson, from Nordland: Surg., Gynec. & Obst., 51: 449-59, 1930.)

tory or cartilaginous glottis behind. The fissure is triangular at rest, linear in phonation, and lozenge-shaped in respiration. When a diphtheritic membrane threatens to embarrass respiration, the glottic slit may be kept open by the introduction of an intubation tube. The tube holder and tube are introduced along the base of the tongue until the epiglottis is reached. The epiglottis is raised with the index finger, and the tube is introduced into the glottis *posterior to the vocal cords* and is released from the holder.

The INFRAGLOTTIC COMPARTMENT of the larynx extends from the true vocal cords to the first tracheal ring (Fig. 164). Inflammatory processes cause *swelling of the mucosa*, manifest particularly in the infant by symptoms of spasmodic croup (laryngismus stridulus).

CERVICAL TRACHEA. The cervical trachea, measuring about 6.5 cm. in length, is flattened *on its posterior surface* because of the deficiency in the cartilaginous rings. The cartilage arrangement keeps the trachea distended and permits a certain degree of elasticity. Mobility is enhanced by the loose cellular tissue which *surrounds the tube, so that it may be deviated* from one side to the other with little difficulty.

VESSELS AND NERVES. The ARTERIAL supply to the larynx is derived from two sources (Figs. 168 to 171). The *superior laryngeal artery*, a branch of the superior thyroid, perforates the thyrohyoid membrane in company with the internal laryngeal veins. The inferior laryngeal branch of the *inferior thyroid artery* accompanies the recurrent laryngeal nerve to *the lower part of the larynx.*

Study of the LYMPHATIC DRAINAGE of the larynx is extremely important because of the incidence of cancer in this region and the extent of operative intervention required to remove it.

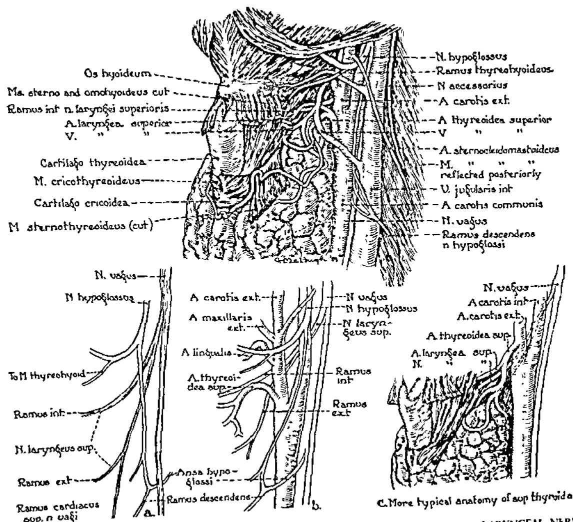


Fig. 169. DISSECTION TO SHOW THE EXTRALARYNGEAL RELATIONS OF THE SUPERIOR LARYNGEAL NERVE.
(From Nordland: Surg., Gynec. & Obst., 51: 449–59, 1930.)

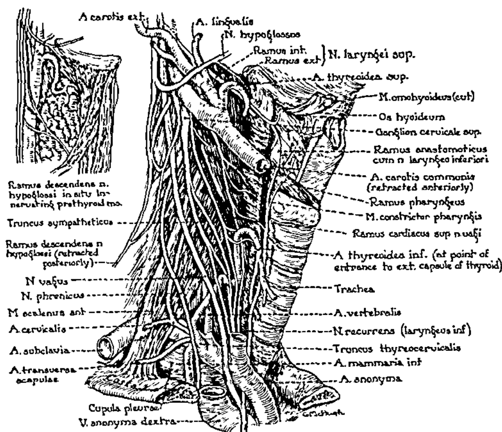


Fig. 170. DISSECTION OF THE RIGHT SIDE OF THE NECK TO SHOW RELATIONS OF THE SUPERIOR AND INFERIOR LARYNGEAL NERVES.

(From Nordland: Surg., Gynec. & Obst., 51: 449–59, 1930.)

The lymphatics are most numerous about the supraglottic area and communicate with the lymph vessels of the pharynx. There are few lymph vessels in the infraglottic area and exceedingly few at the level of the glottis. The group from the supraglottic area drains to the superior deep cervical lymph nodes. Vessels from the anterior part of the lower larynx drain to several small prelaryngeal and pretracheal glands. The group draining the posterior segment of the infraglottic compartment empties through the recurrent glands to the inferior deep cervical lymph chain. The cervical-tracheal lymphatics drain posteriorly to the deep cervical glands (Fig. 155).

The NERVE MECHANISM, by means of which the laryngeal muscles are coordinated and their mucous membranes sensitized, involves motor and sensory nerves. These nerves are the superior and inferior laryngeal branches of the vagus. The *superior laryngeal nerve* arises from the ganglion nodosum and, after a short course, divides into two branches, a small external and a large internal (Figs. 168 to 171). The external branch passes downward, gives a branch to the inferior constrictor muscle of the pharynx, and is distributed finally to the cricothyroid muscle. These muscles change the position of the cricoid and thyroid cartilages, and by so doing lengthen, or tense, the vocal cords. Paralysis of the cricothyroid muscles causes the voice to become weak, rough and easily fatigued. Laryngoscopic examination shows the cords to have a wavy outline. The internal branch passes mesially and enters the larynx through the thyrohyoid membrane. It is distributed to the mucous membranes of the larynx and epiglottis, accounting for the extreme sensitiveness of the laryngeal mucosa. A branch of this nerve passes downward and *anastomoses with ramifications of the inferior* laryngeal nerve. Recent investigations (Nordland, Berlin and Schley) indicate that the internal branch of the superior laryngeal nerve *innervates the interarytenoid muscle in the* majority of cases. Since these muscles approxi-

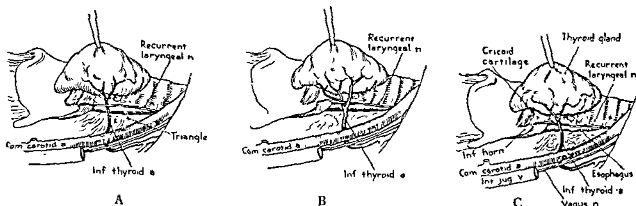


Fig. 171. RELATION OF RECURRENT LARYNGEAL NERVE TO THE INFERIOR THYROID ARTERY IN 86 DISSECTIONS.

A, Lateral, 15 times. B, Passing between arteries and branches, 6 times. C, Medial, 65 times. (From Simon: Am. J. Surg., 60: 212–20, 1943.)

Cartilago thyreoidea
Upper pole of thyroid gland
Cartilago cricoidea
N vagus
N. phrenicus
Esophagus
A. carotis communis
Trachea
A. thyreoidea inf.
A. carotis communis dextra
Tronc. thyreocervicalis
A. subclavia dext.
Sympathetics
N recurrens (laryngeus inf)
A. thyr inf.
A. anonyma
A. subclavia sinistra
A. mammaria int
N. vagus
Arcus aortae
N recurrens
A. pulmonalis
Rami pulmonales
N. vagus
Lung (cut)
Arcus aortae removed to show n recurrens sinister

Fig. 172. DISSECTION OF THE LEFT SIDE OF THE NECK TO SHOW RELATIONS OF THE INFERIOR (RECURRENT) LARYNGEAL NERVE.

(From Nordland: Surg., Gynec. & Obst., 51: 449–59, 1930.)

mate the posterior portions of the vocal cords and are important in phonation, it is essential that their nerve supply, the superior laryngeal nerves, be spared in thyroid surgery. The superior laryngeal nerve from its origin lies parallel to, and in close proximity with, the superior thyroid artery (p. 191).

The *inferior* or *recurrent laryngeal* nerves arise from the vagus at different levels on the two sides (Figs. 168 to 172). On the right the nerve is given off where the vagus crosses the first portion of the subclavian artery, and usually ascends in a groove between the esophagus and larynx.

At the level of the thyroid the nerve is in a posterior position, often at the lower pole, lying 1 to 2 cm. lateral to the trachea. Approaching the latter obliquely as it ascends, it comes to lie in close approximation to the inferior thyroid artery. Simon's illustration (Fig. 171, *A*) shows its great frequency just medial to the branching of this vessel and its occasional pathway lateral to the artery or passing between its branches. Note in Figure 171, *B*, the close relation of the nerve to the upper branches of the inferior thyroid artery. Should these be cut or torn during thyroidectomy, a carelessly applied hemostat is likely to catch the nerve just before it enters the inferior constrictor muscle.

Section of the superior laryngeal nerves is followed at once by a loss of sensation in the laryngeal mucous membrane and a paralysis or relaxation of the cricothyroid muscles. This results in a lowering of the pitch and a diminution in the clearness of the voice. From the loss of sensation there is an inability to perceive the entrance of foreign bodies into the larynx. Transverse section of both inferior laryngeal nerves is followed by complete paralysis of the vocal cords.

Surgical Considerations

LARYNGOSCOPY. Indirect or direct examinations of the larynx may be made through the mouth (Figs. 173, 174). The *indirect*, or mirror, method offers a reflected image of the larynx by use of the principle that, in the reflection of a ray of light, the angle of incidence is equal to the angle of reflection. With good illumination and the tongue drawn downward and forward over the lower incisor teeth, a small mirror is introduced into the mouth, mirror downward. It presses the lower surface of the soft palate backward and upward. In this view the parts reflected first in the mirror are the epiglottis, aryepiglottic folds, and posterior part of the base of the tongue. By tilting the mirror backward, the entrance to the larynx may be seen. The curved outline of the unattached margin of the epiglottis is visible. The anterior extremities of the aryepiglottic folds are hidden by the epiglottis, but the posterior extremities present two rounded elevations. The more medial and posterior elevation is the corniculate cartilage (of Santorini), which surmounts the arytenoid cartilage. The lateral and anterior elevation is the cuneiform cartilage (of Wrisberg). The posterior commissure, an interarytenoid fold of mucous membrane between the corniculate cartilages, varies in width as the summits of the arytenoid cartilages converge toward, or diverge from, each other.

The false cords are much wider apart than the true, are redder, and have but a slight range of movement. The true cords are pearly white and move freely during phonation. Their direction varies with the production of the different tones of the voice, and in variations of respiration. To produce high-pitched notes, the cords are adducted until the chink which separates them is reduced to a linear slit, and only that part of the glottic slit between the arytenoid cartilages (respiratory portion) remains open. In quiet respiration and, to a less

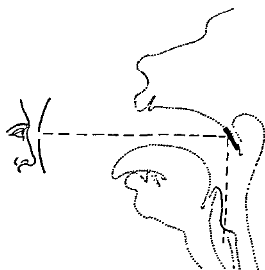


Fig. 173. INDIRECT OR MIRROR LARYNGOSCOPY.

This method utilizes the principle of optics which states that the angle of incidence is equal to the angle of reflection. (After Laurens.)

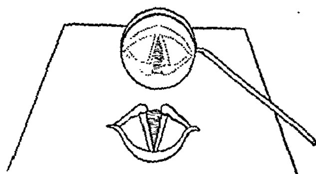


Fig. 174. MIRROR LARYNGOSCOPY.

Reflection in the mirror of the drawn diagram of the larynx. (After Laurens.)

degree, in the formation of low-pitched sounds the slit of the glottis is triangular, with the apex in front. On each side of the laryngeal inlet the laryngoscope reveals the piriform recess. Foreign bodies may be detected in these recesses or in the valleculate depressions between the epiglottis and the root of the tongue.

Direct laryngoscopy consists in examination of the larynx through the mouth, using a speculum to displace the tissues that otherwise would obstruct the view (Fig. 175). It is required often for inspection supplementary to the mirror examination, and is the only method applicable to children under four or five years of age, since they will not tolerate the use of a mirror. With its use, foreign bodies, new growths and biopsy specimens can be removed.

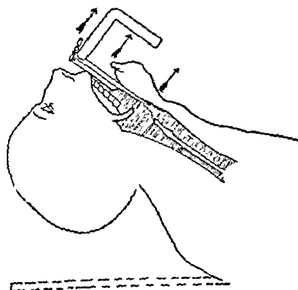


Fig. 175. SCHEMA ILLUSTRATING DIRECT LARYNGOSCOPY ON THE RECUMBENT PATIENT.

The motion is imparted to the tip of the laryngoscope as if to lift the patient by his hyoid bone. (Jackson, in Jackson and Coates: The Nose, Throat, and Ear and Their Diseases.)

LARYNGOTOMY. Incision into the cavity of the larynx is accomplished in a number of ways and is necessitated by a number of conditions, chiefly the presence of foreign bodies lodged in the larynx, or as a preliminary step to extensive operations on the mouth. The entrance to the larynx and supraglottic area may be exposed by the infrahyoid pharyngotomy incision; the glottis by median longitudinal section of the thyroid cartilage, thyrotomy; and the infraglottic area by the intercricothyroid laryngotomy incision.

Infrahyoid laryngotomy or, better, *pharyngotomy* is accomplished by a transverse incision along the inferior margin of the hyoid bone. The infrahyoid muscles and thyrohyoid membrane are incised, and the pharynx is opened. The operation affords exposure of the entrance to the larynx, the lower end of the pharynx and the beginning of the esophagus.

Thyrotomy is the type of laryngotomy which contemplates midsagittal splitting of the thyroid cartilage, thereby avoiding the insertion of the vocal cords. When the two plates of the cartilage are retracted laterally, the excellent exposure afforded the interior of the larynx makes possible the removal of new growths or foreign bodies. Increased exposure may be obtained by extending the thyrotomy incision upward through the thyrohyoid membrane and downward through the cricoid cartilage and the first tracheal ring (Fig. 176).

The *intercricothyroid* incision, made transversely above the cricoid cartilage, avoids section of the cricothyroid artery, approaches the larynx in its most accessible, superficial and bloodless area, and, except in children, opens a sufficient interval to permit the introduction of a laryngotomy tube. This incision, long taught as an emergency measure, should be abandoned in almost all instances because it predisposes to laryngeal stenosis. The preferable location for operative intervention is the trachea at a level well below the larynx.

TRACHEOTOMY. Incision into the trachea is undertaken for the relief of menacing asphyxia or as a procedure preliminary to operations on the larynx (Fig. 176). Obstructive laryngeal dyspnea arises in the course of many different diseases; when indicated, tracheotomy should be done before the emergency arises, since hasty tracheotomy may be done too high, with increased likelihood of laryngeal stenosis.

An anatomic picture of all the blood vessels

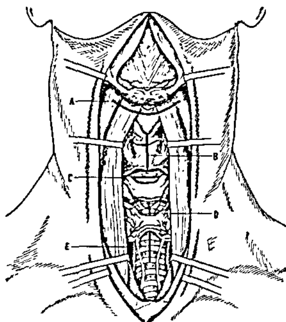


Fig. 176. POSITION OF INCISION FOR OPENING THE LARYNGOTRACHEAL TUBE.

A, Infrahyoid laryngotomy (subhyoid pharyngotomy); *B*, thyrotomy; *C*, intercricothyroid laryngotomy; *D*, high tracheotomy; *E*, low tracheotomy, which is most desirable (Keen).

and structures in front of the neck is likely to devastate the confidence of one confronted with performing an emergency tracheotomy. Essentially, only these facts merit consideration: the thyroid cartilage is easy to find; the trachea extends down the median line of the neck to the suprasternal notch; incision can be carried down the midline without endangering any important structure; all the structures that must not be cut are at the sides; and the cricoid cartilage is the only complete ring in the lower air passages and should not be cut unnecessarily. These facts are the fundamentals incorporated in the "tracheotomy triangle of Jackson."

Under favorable operative conditions the technique of tracheotomy is as follows: A midline incision dividing the skin and fascia is made from the thyroid notch to the suprasternal fossa, the cricoid cartilage is located, and the deeper dissection is continued below it, after the infrahyoid (ribbon) muscles have been separated. If the thyroid isthmus is obstuctive, it may be retracted upward; if large, it should be ligated and divided, lest it slip over and interfere with the availability of the tracheal incision in postoperative care. The corrugated surface of the trachea can be located accurately by palpation, and incision into it should be as low as possible. The cricoid cartilage should not be cut, since stenosis is almost certain to follow the wearing of a cannula in this position.

Cut-Throat Wounds. The cut-throat incision, either suicidal or homicidal, most frequently involves the thyrohyoid interval of the infrahyoid space. Throwing back the head to inflict the wound often retracts the carotid sheath and its structures to a protected position under the sternocleidomastoid muscles. When a wound occurs *across the thyrohyoid space*, the anterior jugular veins, superior laryngeal nerve, superior thyroid artery, sternohyoid and omohyoid muscles and the thyrohyoid membrane are divided. The inferior constrictor muscle also is cut, and its upper portion may drop back, thus causing respiratory obstruction.

When the incision is *above the hyoid bone*, the anterior jugular vein, the mylohyoid, hyoglossal, genioglossal and geniohyoid muscles are divided. The lingual vessels and hypoglossal nerves are severed, but the lingual nerve usually lies above the level of the wound. The external maxillary vessels are the first large vessels severed; the elements in the carotid sheath are uninjured save when the wound is extensive. The substance of the tongue may be cut and the floor of the mouth be opened. When the anterior attachment of the tongue is severed, the tongue is likely to fall backward, push down the epiglottis, and produce suffocation (*cf.* Fig. 164).

Wounds occasionally are low and *involve the trachea and cricothyroid space.* These wounds reach the carotid sheath vessels more readily than do transverse wounds in any other part of the neck. Many instances, however, have been reported in which the trachea and esophagus have been divided without injury to any of the great vessels.

THYROID REGION

Thyroid Gland and Its Divisions. The thyroid gland, with its parathyroid bodies, occupies an exceedingly important place in surgical physiology and pathology. It consists of two somewhat conical or pyramidal lateral lobes united by an isthmus, and is firmly bound by fibrous tissue to the anterior and lateral the aspects of larynx and to the upper

trachea. There are many variations in the size, shape and relative level of the gland (Fig. 179). A vertical prolongation known as the *pyramidal lobe* occasionally arises from the isthmus. This lobe may extend in front of the cricoid and thyroid cartilages toward the hyoid bone, to which it may be attached by a fibromuscular flap or slip. The thyroid is surrounded by a sheath formed by extensions from the pretracheal fascia (Fig. 157). This sheath is separated from the true capsule of the gland by areolar tissue, in which run vessels and nerves.

The upper extremity of each *lateral lobe* lies against the posterosuperior portions of the wings of the thyroid cartilage and the walls of the pharynx. The superior thyroid vessels which reach it at this level constitute its upper vascular or superior thyroid pedicle. The rounded lower extremity of each lobe extends to the level of the fifth or sixth tracheal ring, and is related to the inferior thyroid pedicle, in which the veins lie more superficially than the arteries. The inferior extension of this pole may reach to the level of or below the suprasternal fossa (*substernal thyroid*).

The convex surface of the gland is in relation with the infrahyoid muscles; only the pretracheal fascia intervenes. An enlarged lateral lobe may press upon and thin out these muscles until they are almost unrecognizable. The posterolateral surface is grooved by contact with the common carotid artery, and is related to the prevertebral muscles and the sympathetic gangliated chain. The most important surgical relation is with the recurrent laryngeal nerve as it ascends in the tracheo-esophageal sulcus. The mesial surfaces of the thyroid lobes embrace the lateral surface of the tracheal and cricoid cartilages and the inferior and lateral parts of the pharynx and esophagus. These relations explain the difficulties in respiration, deglutition and phonation caused by large goiters.

The *thyroid isthmus* occupies a variable level, and occasionally is absent. In the adult it usually overlies the second, third and fourth tracheal rings. An enlargement of the substance of the pyramidal lobe may penetrate into the mediastinum as a retrosternal or plunging goiter. If interposed between the sternum and trachea, it may cause pressure suffocation.

Development. The thyroid gland makes its appearance as an evaginating bud from the entodermal lining of the anterior pharyngeal wall (Fig. 177). This bud has its origin at a point which later becomes the foramen caecum of the tongue. It takes on a tubular growth (thyroglossal duct) which extends downward and forward, and it widens laterally at its inferior extremity to become the lateral thyroid lobes. Usually nothing remains of this median segment but the thyroid isthmus. In many cases the existence of the duct is shown by the form of the pyramidal lobe (Fig. 179).

In the vicinity of the thyroid gland, and par-

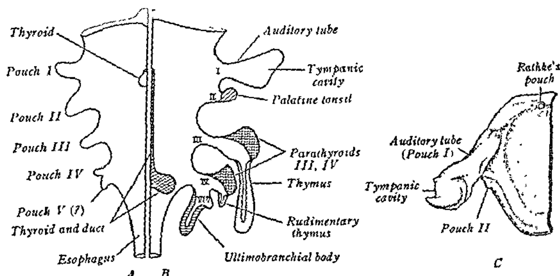


Fig. 177. DERIVATIVES OF THE HUMAN PHARYNX.

A, Right half in ventral outline, showing the entodermal pouches and the thyroid diverticulum in the embryo of 4 weeks. *B*, Left half of the pharynx in a 6 weeks' embryo, illustrating the sites of origin of tympanic, tonsillar and glandular derivatives. *C*, Reconstruction (in dorsal view) of the left half of the pharynx of an embryo of 8 weeks. (Arey: *Developmental Anatomy*.)

ticularly along the thyroglossal duct, small glandular masses frequently are found which present the same structure as the thyroid. In incomplete obliteration of the thyroglossal duct these masses may be found at any or all levels from the foramen caecum to the thyroid isthmus. They may be located within the thickness of the base of the tongue, in front of, within or behind the hyoid bone, or, as is most usual, below the hyoid bone and above the thyroid isthmus. They may replace the pyramidal lobe wholly or in part, and occasionally are found inferior to the thyroid gland.

Perithyroid Sheath and Thyroid Capsule. The pretracheal fascia loosely invests the thyroid gland with a variable fascial covering which is thickest and densest over the lateral surface of the thyroid cartilage, where it holds the superior pole of the gland firmly in place. This so-called *sheath* or false capsule usually is thin, transparent, and easy to separate; it allows dislocation of the gland to expose the thyroid vessels.

When freed from the perithyroid sheath, the thyroid parenchyma is bound by its *capsule*, a densely adherent peripheral condensation of the connective tissue of the gland, wherein the thyroid vessels anastomose in a rich network. Large vessels lie in the capsule, but the branches which leave it to supply the substance of the gland are of small caliber. The capsular arrangement of vessels makes partial thyroid excision or removal of an adenoma a relatively bloodless procedure when the vessels are clamped severally in the supporting structure of the gland.

Parathyroid Bodies. The parathyroids, ordinarily four in number, are small, oval or bean-shaped bodies ranging from 3 to 8 mm. in length, 2 to 4 mm. in width, and 1 to 3 mm. in thickness (Fig. 182). Accessory fragments of parathyroid tissue generally are present about the thyroid gland or along the trachea. Parathyroid tissue varies from yellowish-orange to pinkish-brown or brownish-red, according to the degree of vascularity and the amount of fat beneath the parathyroid capsule. Microscopic examination reveals a structure resembling that of the medulla of the adrenal glands. The parathyroids are not likely to be removed if intracapsular resection of the thyroid is performed (Fig. 178). Their excision causes death

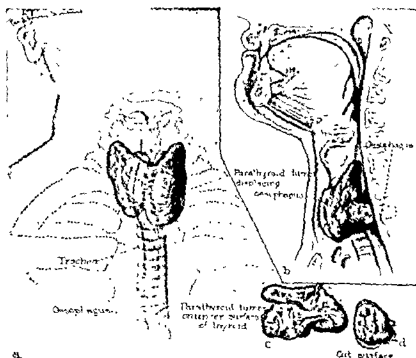


Fig. 178. PARATHYROID ADENOMA.

a, Anteroposterior view shows the deflection of the esophagus to the right; *b*, left lateral view demonstrates the retrotracheal position of the adenoma; *c*, comparative size of the adenoma and that of the thyroid gland. (From Goldman and Smyth: Ann. Surg., 104: 971–81, 1936.)

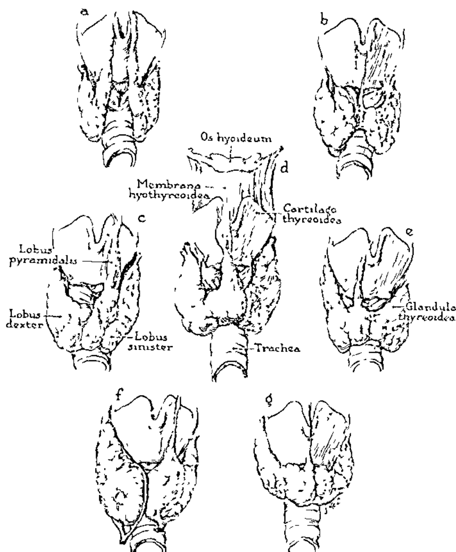


Fig. 179. THYROID GLAND: VARIATION IN FORM AND SIZE.

The gland may be disposed in 2 separate postions (*a*); the pyramidal lobe may lie in or near the median plane (*b*, *c* and *g*), to either the right (*e*) or to the left thereof (*c* and *f*).

by tetany unless their secretion is supplied artificially.

The *superior parathyroids* ordinarily lie either on the posterior surface of the thyroid gland near the junction of the upper and middle thirds, or along the branches of the superior thyroid artery. The *inferior parathyroids* usually lie on the posterior surface of the gland near the inferior margin of the lateral lobes. The relation of the parathyroids to the superior and inferior thyroid arteries and to their larger anastomotic branches is fairly constant.

Studies at the University of California Hospital based upon operative findings and cadaver dissections have shown that in 30 per cent of cases one or more of the parathyroids is located on either the lateral or anterior part of the thyroid capsule. These parathyroids are removed in thyroidectomy unless care is taken to preserve part of the anterior and the lateral, as well as the posterior, part of the capsule (Millzner).

The connection between hyperplasia or tumor of the parathyroids and osteitis fibrosa cystica (von Recklinghausen's disease) has stimulated much investigation. So constant is this association that parathyroid enlargement must be ruled out surgically in cases of osteitis fibrosa cystica. Hyperparathyroidism causes excessive mobilization of the skeletal calcium and results in hypercalcemia. Removal of the hyperplastic parathyroid or of the parathyroid tumor stops oversecretion and allows redeposition of calcium into the skeleton, a process which takes place within a short time.

THYROID VESSELS AND NERVES. *Operative*

procedure on the thyroid gland requires an exact knowledge of its vessels and their relations to neighboring nerve trunks and to the parathyroid bodies. The thyroid gland is supplied by two paired arteries, the superior and the inferior thyroid, and sometimes a single artery, the thyroidea ima (see vein, Fig. 181).

The *superior thyroid artery* is the first branch of the external carotid (Fig. 182). It arises opposite the thyrohyoid interval, a little above the thyroid cartilage, and is directed caudally and mesially, deep to the infrahyoid muscles. It lies on the outer surface of the inferior constrictor of the larynx, with the superior laryngeal nerve situated only a little higher up (p. 183). This nerve may be included in ligation of the superior thyroid artery unless care is exercised. Its terminals anastomose within the gland with those of the inferior thyroid and the superior thyroid arteries of the opposite side. The superior thyroid artery may be ligated near its origin by an incision similar to that

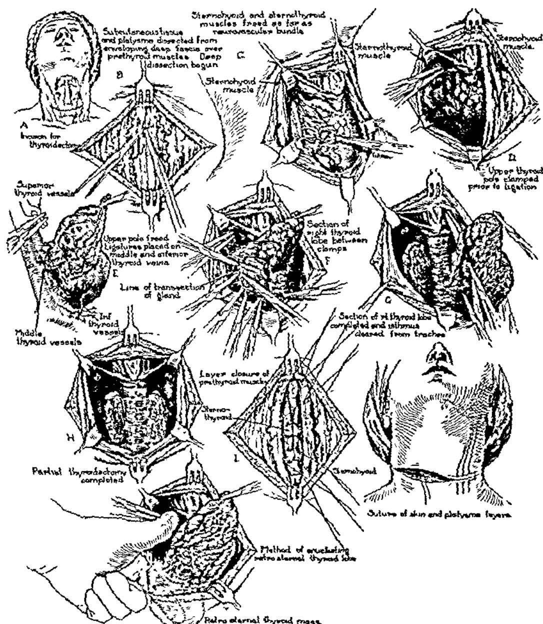


Fig. 180. SUBTOTAL THYROIDECTOMY.

(Modified from Mont Reid.)

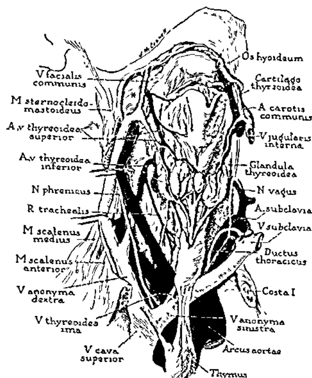


Fig. 181. BLOOD VESSELS, GLANDS AND RELATED STRUCTURES IN THE NECK. ANTEROLATERAL VIEW

The sternocleidomastoid muscle, the infrahyoid musculature and the cervical fascia (including the carotid sheath), the sternum, clavicles and sternal portions of the ribs have been removed. Showing, especially, the arteries and veins of the thyroid gland and thymus, and *the vessels related to the terminal portion of the thoracic duct (lower right) and the sub*maxillary gland (upper left, at *).

used for ligation of the external carotid (p. 219). The *inferior thyroid artery*, the larger and more important, arises from the subclavian artery by way of the thyrocervical trunk and turns mesially at a point about 2 cm. below the carotid tubercle; at this point it runs toward the gland in an arched course with the convexity upward (Figs. 170, 172, 181). It may approach the gland directly by a downward curve. The arch of the artery crosses anterior to the gangliated sympathetic chain and the middle cervical ganglion. The segment of the artery proximal to its division into terminal branches has important relations with the recurrent laryngeal nerve, which runs upward in the tracheo-esophageal sulcus and enters the muscles of the larynx (Fig. 182). The nerve lies either in front of the artery, among its branches, or behind them (Fig. 171).

The *thyroidea ima*, which branches from the innominate trunk or from the aortic arch, varies in size from a small arteriole to a vessel as large as the inferior thyroid. It runs upward over the anterior surface of the trachea to the inferior border of the thyroid gland. It may co-exist with the inferior thyroid artery or may replace it. The possible presence of the vessel is to be borne in mind in low tracheotomy (Fig. 181).

The thyroid arteries anastomose so thoroughly with those of the trachea and the esophagus that the trunks of all the thyroid arteries may be ligated without fear of necrosis of the gland.

The thyroid *veins* constitute part of the intricate system of venous channels situated in the front of the neck and the anterior mediastinum; they are crossed transversely and vertically by veins which drain the superficial musculature of the face and neck and the related fascia and integument (Fig. 185).

The thyroid *nerve supply* is derived from the sympathetic ganglia. The fibers from the middle and inferior cervical ganglia reach the gland as networks on the superior and inferior thyroid arteries. Excitation of these nerves may account for some of the symptoms and signs of exophthalmic goiter.

Surgical Considerations

THYROIDECTOMY. The successive steps of a subtotal thyroidectomy are portrayed in Figure 180.

The incision through the skin, su

fat, and platysma should be practically transverse, since removal of the goiter allows the upper flap to sag and results in a slight curve downward in the middle of the incision. If the incision is originally curved downward, the later sag is too great. The line of incision should be low, about one fingerbreadth above the clavicles, which will generally permit the resultant scar to be covered by a string of pearls. Women patients appreciate such niceties.

In dissecting the superior pole of the thyroid, Coller has always taught the highly efficient maneuver of developing the space between the cricothyroid muscle and the gland by careful separation with a hemostat. Then, with one index finger in this space and the other on the lateral side of the gland, the superior pole is well mobilized for division of the pole vessels and ultimate rolling forward and downward of often high and deep superior pole prolongations.

Two serious complications of thyroidectomy can largely be avoided by anatomic knowledge. The recurrent laryngeal nerves are damaged far too often, and examination of the vocal cords for paralysis should be made preoperatively and postoperatively. Voice changes from a unilateral injury are often not great enough to make the damage apparent. The relation of the nerve to the thyroid gland and the inferior thyroid artery from various angles is shown in Figures 170, 172 and 182 to emphasize the possibility of injury by haphazard ligation or clamping of vessels in this area. Some surgeons avoid the area entirely, placing hemostats on the branches of the inferior thyroid artery within a lateral and posterior protecting portion of the gland capsule and substance. The

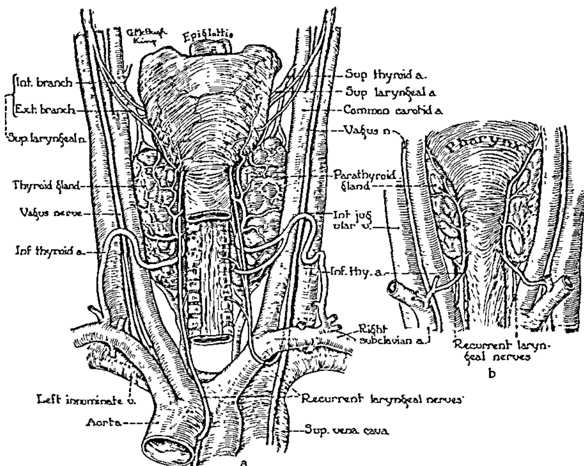


Fig. 182. POSTERIOR VIEW OF THYROID, TRACHEA AND ESOPHAGUS TO SHOW THE COURSE OF THE THYROID ARTERIES AND THEIR RELATIONS TO THE LARYNGEAL NERVES.

a, Accurate drawing from dissections; *b*, inaccurate representation. (From Nordland: Surg., Gynec. & Obst., 51: 449–59, 1930)

same procedure obviates a second serious complication of thyroidectomy, that of damage to the parathyroid bodies. Equally good surgeons advise exposing the recurrent laryngeal nerves for their careful preservation, and with experience this is not difficult to do once their position is learned.

Total thyroidectomy is now done only for malignancy, which of course requires knowledge and skill to avoid injury to the recurrent laryngeal nerves and parathyroids.

The superior laryngeal nerves are much less vulnerable to damage during thyroidectomy than the recurrents, but their position should be thoroughly known to guarantee their protection (Figs. 169, 170).

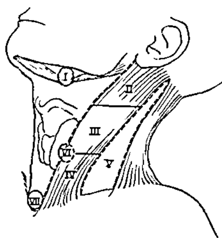


Fig. 183. NODE-BEARING AREAS REMOVED BY RADICAL NECK DISSECTION FOR THYROID CANCER.

Level I, submaxillary; level II, upper jugular; level III, middle jugular; level IV, lower jugular; level V, accessory chain; level VI, juxtathyroid; level VII, anterior mediastinal nodes. (From Frazell and Foote: Cancer, 8: 1164, 1955.)

PATHS OF APPROACH FOR LIGATION OF THE THYROID VESSELS. Ligation of the superior thyroid artery was once a part of the multiple-stage operative treatment of severe hyperthyroidism, but with modern preoperative preparation—the use of thiouracil derivatives, and the like—the procedure is now rarely needed. The *superior thyroid artery* may be ligated through a small transverse incision located in a skin fold (Fig. 160). The incision should be directly over the point where the superior thyroid vessels enter the upper poles of the gland. This point can be determined only by palpating the gland against the thyroid cartilage. The pole of the thyroid rests directly

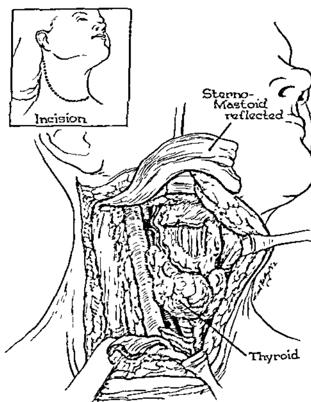


Fig. 184. LESS CONSPICUOUS SCAR FOR LYMPH NODE DISSECTION IN CASES OF PAPILLIFEROUS CARCINOMA OF THE THYROID.

Sternocleidomastoid muscles are resutured, and submental and submaxillary triangles then resected. (From Eckert and Byars: Ann. Surg., 136: 83, 1952.)

against the internal jugular vein and common carotid artery. Adequate exposure, therefore, should be made. The fibers of the omohyoid and the sternohyoid are separated longitudinally, and the fibers of the sternothyroid are cut across for the same distance as the skin incision. The internal jugular vein and common carotid artery are retracted, and the superior thyroid vessels are ligated. Ligation at the level of the superior pole of the gland best insures avoidance of the superior laryngeal nerve.

Ligation of the *inferior thyroid artery* as a single procedure is seldom indicated.

Radical Neck Gland Dissection for Cancer of the Thyroid. The forms of carcinoma of the thyroid other than the papillary type are generally agreed to require total thyroidectomy and radical dissection of the lymph glands of the neck, as shown in Figures 206 to 210.

Considering the papillary type of carcinoma, which is the most frequent kind, some disagreement exists as to whether the complete radical procedure with its disfiguring appearance because of removal of the sternocleidomastoid muscle should be done. For this seemingly low grade malignancy, Crile believes that total thyroidectomy combined with local excision of metastatic nodules is adequate. Many others advocate radical removal of the primary lesion and the regional lymph nodes. Proponents of this school are in general agreement that radical dissection should be carried out in conjunction with thyroidectomy when there is clinical or other evidence of cervical lymph node metastases; however, opinions are varied as to whether or not radical neck dissection should be done in the absence of clinical or other evidence of cervical lymph node involvement. Figure 183 is a schematic outline of the

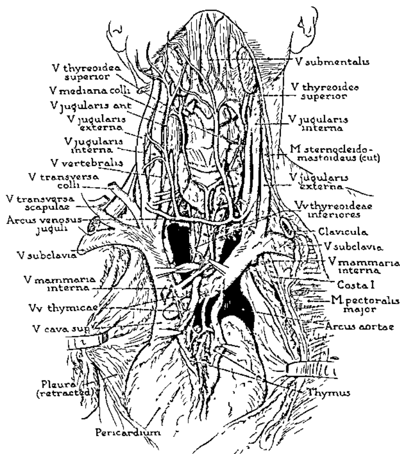


Fig. 185. SUPERIOR VENA CAVA AND THE AORTA, WITH JUGULAR AND SUBCLAVIAN TRIBUTARIES OF THE CAVAL VEIN AND LARGER BRANCHES OF THE AORTIC ARCH.

The thoracic wall has been removed and the pericardial sac opened; in the neck the dissection has been carried to the level of the thyroid gland. Both the superficial and deep veins are shown, including the vessels of superficial level (cranialward to those which descend from the mandibular region), the veins which drain the thyroid gland and the thymus.

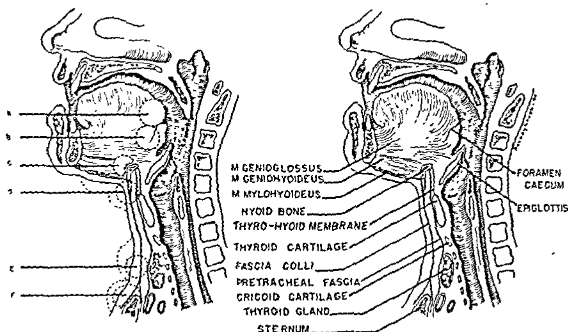


Fig. 186. LOCATION OF VARIOUS REMNANTS OF THE THYROGLOSSAL TRACT.

A, In front of the foramen caecum. *B*, At the foramen caecum. *C*, Suprahyoid. *D*, Infrahyoid. *E*, In area of thyroid gland. *F*, Suprasternal. (From Ward, Hendrick and Chambers: Surg., Gynec. & Obst., 89: 727-34, 1949.)

various node-bearing areas intended to be removed by the procedure of radical neck dissection as shown in Figures 206 to 210. Table 2 shows the percentage of nodes involved with metastases in the various areas. It is important to note that 96 per cent of the 115 *clinically* positive or doubtfully positive cases were positive. Even more important was the incidence of 61.2 per cent positive nodes in the sixty-seven *clinically negative cases. This group* was four times more likely to have their metastases limited to a single area than those showing some clinical sign of local metastasis.

Frazell and Foote* presented their material as an argument based on anatomical evidence that, if a surgeon subscribes to the radical surgical approach, he must logically extend this to those patients with thyroid cancer and if he fails to do so, in some 60 per cent of cases

Table 2. Pathological Findings in 182 Radical Neck Dissections for Papillary Carcinoma of the Thyroid Gland, 1946–53

	Node Metastases		
	Clinically Negative	Clinically Positive	Clinically Doubtful
Total	67	104	11
Neck dissections with node metastases proved pathologically	41 (61.2%)		113 (96%)

From Frazell and Foote: Cancer, 8: 1164, 1955.

* Frazell, E. L., and Foote, F. W., Jr.: Papillary Thyroid Carcinoma: Pathological Findings in Cases with and without Clinical Evidence of Cervical Lymph Node Involvement. Cancer, 8: 1164, 1955.

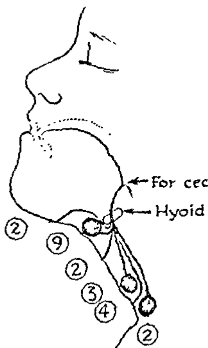


Fig. 187. LOCATION OF CYSTS OR FISTULAS OF THE THYROGLOSSAL DUCT IN 22 CASES.

(From Bill, Jr.: S. Clin. North America, 36: 1599-1611, 1956.)

knowingly leaves removable local lymph nodes involved with carcinoma. Whether this logic will be practical remains for the future to show. Extremely long-term follow-up will be required. Theoretically, the long-range prognosis should favor those patients adequately treated earlier in their disease. If this does not occur, *then we must admit* that this type of thyroid cancer differs unaccountably from other forms of cancer on which early treatment is generally considered desirable.

LESS CONSPICUOUS INCISION FOR LYMPH NODE DISSECTION IN CARCINOMA OF THE THYROID. In an effort to spare disfigurement, particularly in women, who make up five out of six cases of papilliferous carcinoma of the thyroid, Eckert and Byars* extend the usual low transverse thyroid incision upward, as shown in Figure 184, and do a modified radical neck gland dissection. The sternocleidomastoid muscles are resutured; the submental and submaxillary triangles are then resected.

THYROLINGUAL OR THYROGLOSSAL DUCT

* Eckert, C., and Byars, L. T.: The Surgery of Papillary Carcinoma of the Thyroid Gland. Ann. Surg., 136: 83, 1952.

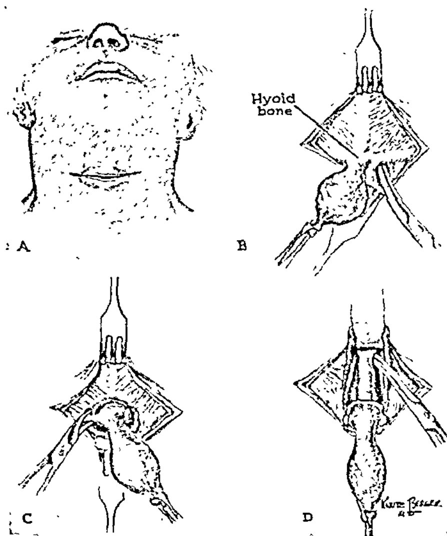


Fig. 188. TECHNIQUE OF REMOVAL OF CYST OR FISTULA OF THE THYROGLOSSAL DUCT.

A, The incision should be transverse or transverse-elliptical. *B*, The cyst or fistula is dissected upward to the level of the *hyoid bone*. *C*, The hyoid bone is freed of its *muscular attachments for 1 cm. on each side of the midline*, and the bone is cut on each side. *D*, With the hyoid still attached, a core of tissue containing the fistula is dissected up to the base of the tongue. This point can be identified by the forefinger of an assistant placed in the mouth at the base of the *tongue and pushing* the tongue toward the wound. The dissection is stopped at the whitish under surface of the mucous membrane. By this method the whole of the tract will be excised. (From Bill, Jr.: S. Clin. North America, 36: 1599–1611, 1956.)

CYSTS, SINUSES AND FISTULAE. These embryological remnants may persist anywhere along the line between the foramen caecum at the base of the tongue and the suprasternal notch (Fig. 187). They develop from epithelial arrests in the remnants of the thyroglossal duct produced by descent of the thyroid primordium. Normally, the epithelium lining the tract undergoes degeneration and disappears, but failure to do so results in cysts or fistulae. Figure 187 shows the location of such abnormality in twenty-two cases operated upon, usually because infection of the tract develops.

The essential technique for excising a thyroglossal cyst or sinus requires knowledge and care (Fig. 188). Note should be made of the fact that 1 or 2 cm. of the central portion of the hyoid bone commonly need to be excised because the tract frequently goes just anteriorly or through or just posteriorly to this structure. The tract also commonly extends upward to the base of the tongue, and complete excision is necessary to cure the condition. The surgeon should be prepared to encounter any one of many variations in course of the tract; they can be demonstrated beforehand by methylene blue injection.

CERVICAL ESOPHAGUS

DEFINITION AND BOUNDARIES. The musculomembranous cervical esophagus is the direct continuation of the pharynx, the one merging with the other opposite the inferior margin of the cricoid cartilage at the level of the body of the sixth cervical vertebra. The carotid tubercle (p. 166) marks this level and is an important landmark in lateral esophagotomy.

ANATOMIC SUMMARY. The *esophagus*, as well as the pharynx, is attached loosely to the prevertebral fascia by sagittal septa, which form retropharyngeal and retro-esophageal spaces. Abscesses in these spaces are hindered from lateral extension by the septa, and fuse toward the mediastinum.

In the cervical region the trachea does not cover the esophagus completely, but leaves a portion of its left anterior margin exposed, affording natural surgical access. Despite its proximal fixation with the pharynx, the esophagus is capable of considerable upward and lateral displacement because of its intrinsic elasticity and loose connection with the trachea and prevertebral fascia.

The esophagus, when empty, is flattened anteroposteriorly, its lumen appearing as a transverse slit; when distended, it is irregularly cylindrical in form, presenting *constrictions at certain points*. The first and narrowest of these constrictions is at the beginning of the esophagus.

RELATIONS. The loose peri-esophageal tissue *may be infected after injury to, or inflammation of*, the walls of the esophagus, such as is caused by foreign bodies or faulty instrumentation. Its chief lateral relation is with the *carotid artery, which lies 1 to 2 cm. from it*. Deviation of the esophagus to the left relates it more intimately with the elements of the carotid sheath and the thyroid lobe on that side. The esophagus is close to the recurrent laryngeal nerves, which lie in the tracheo-esophageal sulci, to the gangliated sympathetic chains, and to the inferior thyroid arteries.

The posterior portions of the lateral thyroid lobe, when enlarged, may send out prolongations which insinuate themselves between the trachea and the anterior surface of the esophagus (retrotracheal and pre-esophageal). Prolongations may extend between the esophagus and prevertebral fascia and cause difficulty in swallowing.

Surgical Considerations

EXAMINATION OF THE ESOPHAGUS. Roentgenograms in examination of the esophagus have been of great value, not only in detecting foreign bodies lodged at the normal constrictions, but also *in demonstrating carcinoma*, ulcers, diverticula and strictures.

Esophagoscopy must be done for the early diagnosis and treatment of esophageal lesions. Use of the esophagoscope requires accurate anatomical knowledge, dexterity, gentleness, and the cooperation of the patient. With the obturator *in position, the esophagoscope* is passed beyond the constriction at the esophageal inlet, whereupon the obturator is removed and the illuminated examining tube is passed downward under the direct vision of the operator. The closed cervical esophagus unrolls before the advancing instrument. Through the esophagoscope, *local conditions may be treated*, foreign bodies removed, strictures dilated, and biopsy tissue obtained.

OBSTRUCTION OF THE ESOPHAGUS. *A fibrous* or cicatricial constriction of the esophagus may result from the healing of *an ulcer, from traumatic* or chronic inflammation *(syphilitic or*

tuberculous) or from the swallowing of a corrosive or a hot liquid. The commonest cause of stricture in children is the swallowing of commercial lye, thoughtlessly left about the kitchen. The first and chief symptom of obstruction is difficulty in swallowing (dysphagia), which becomes more pronounced until swallowing is impossible and regurgitation supervenes. With high stenosis, regurgitation is almost immediate; with low stenosis, and especially with proximal dilatation, it is delayed.

In adult life, carcinoma is the commonest cause of esophageal obstruction. The growth ulcerates the wall early and invades the deep cervical and posterior mediastinal lymph nodes (mediastinitis). It presents the same difficulty in swallowing as does that accompanying ordinary cicatricial stenosis, and is followed quickly by regurgitation.

PHARYNGO-ESOPHAGEAL DIVERTICULA. A diverticulum or outpocketing of the wall may occur in any part of the esophagus, but is most frequent in the upper part because of the weakness in the longitudinal muscle layer at the level of the cricoid cartilage (Fig. 189). The high diverticula of the posterior wall of the pharyngo-esophageal region are of the greatest interest, since they are accessible surgically.

Esophageal diverticula may be congenital, the consequence of dilation proximal to a stricture, the result of pressure from within on a weak point of the wall, or of traction from without from the healing and subsequent cicatricial contraction of a peri-esophageal inflammatory process (diseased lymph nodes).

Food or any substance opaque to the x-ray ordinarily goes to the stomach only after the diverticulum has been filled, so that under the fluoroscope the pouch may be seen to fill and then to overflow into the esophagus. The most common site of a pulsion diverticulum is at the junction of the hypopharynx with the esophagus (Fig. 189). At one time a two-stage procedure, designed to prevent a descending mediastinitis, was used to excise a diverticulum. Now, with better technique in handling the esophagus, which often heals poorly, and the use of antibiotics, a one-stage procedure is commonly done (Fig. 193).

APPROACH TO THE CERVICAL ESOPHAGUS FOR DIVERTICULECTOMY. The esophagus is approached from the left side (Fig. 193), where it is more accessible, unless the diverticulum bulging to the right indicates selection of that route. A method for removing the diverticulum is shown in Figure 194.

PREVERTEBRAL REGION

DEFINITION AND BOUNDARIES. The prevertebral region includes only the thin and narrow

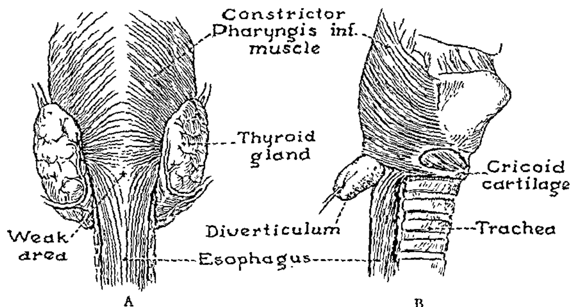


Fig. 189. PULSION DIVERTICULUM OF THE ESOPHAGUS.

A, Posterior view of pharyngo-esophageal region, showing the area at which the esophageal muscular wall gives way; *B*, right lateral view of protruding mucosal sac.

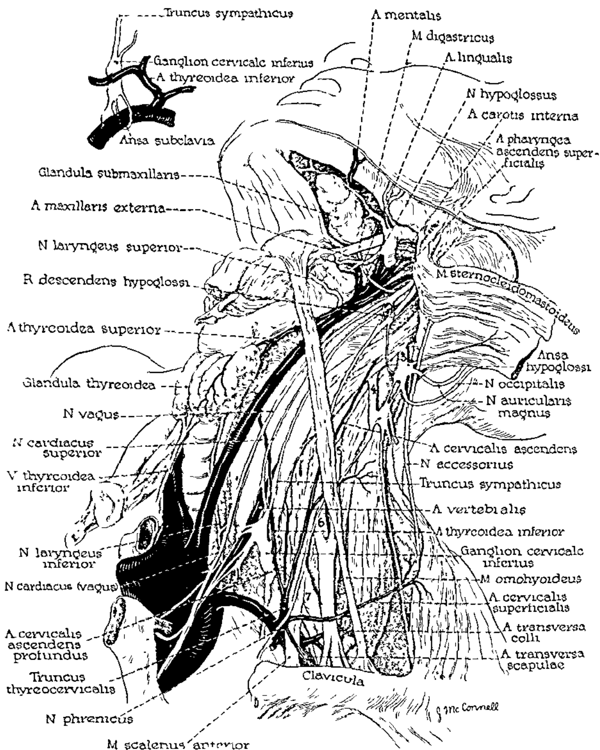


Fig. 190. CERVICAL SYMPATHETIC TRUNK AND GANGLIA IN RELATION TO THE OTHER DEEP STRUCTURES OF THE NECK. ANTEROLATERAL VIEW.

The contents of both the anterior and posterior triangles of the neck have been exposed by reflection of the sternocleidomasteoideus; *the omohyoideus is drawn taut by elevation of the head. The sternum and the upper extremity have been re-*moved, and both pectoral girdles have been carried backward, in order fully to expose the structures at the root of the neck. The infrahyoid muscles remain as cut extremities at the hyoid bone and thyroid cartilage. The aortic arch, *together with its* main branches and the derived arteries, is retained, but the corresponding veins have been excised. The pulmonary artery has been transected near the point at which it is connected with the aortic arch by the arterial ligament (at *), around which passes *the recurrent* laryngeal nerve. The innominate vein remains as a segment where it receives the inferior thyroid vein. Certain of the contributory rami (numbered 3 to 7) and derived nerves of the cervical and brachial plexuses are shown, as well as the cervical sympathetic *trunk and its larger ganglia and related nerves. In this specimen the inferior cervical sym-*pathetic ganglion is large, the superior is of moderate size, a middle ganglionic swelling not distinguishable.

Inset (upper left): Inferior cervical ganglion and the ansa subclavia *in the same specimen. The loop originates in, and returns to, the* inferior ganglion. (From Jamieson, Smith and Anson: Quart. Bull., Northwestern Univ. M. School, 26: 219–27, 1952.)

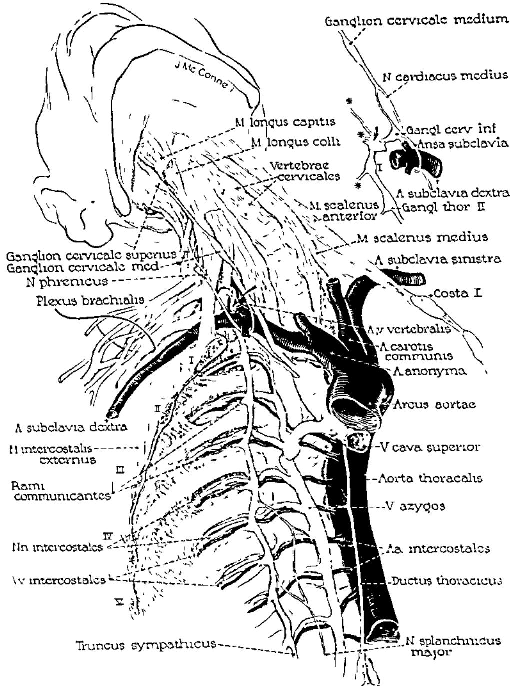


Fig. 191. CERVICAL SYMPATHETIC GANGLIA, WITH RELATED DEEP MUSCLES AND VESSELS OF THE NECK AND THE THORACIC SYMPATHETIC GANGLIA IN RELATION TO THE LARGE BLOOD VESSELS, THEIR BRANCHES AND TRIBUTARIES.

Showing, especially, the ganglionated chain in the neck in relation to the vertebral artery and vein, the longus capitis, longus colli and scaleni; comparably, in the thorax, the segmental continuation of the chain is shown in relation to the vertebral column, the aorta with its intercostal branches, azygos vein and its tributaries and the thoracic duct. For exposure of these structures, the following were removed: the upper extremities and the pectoral girdle; the front of the thoracic cage; the cervical and thoracic organs (lungs, trachea, thyroid gland, thymus and heart); all musculature dorsalward to the level of the scaleni and longus colli; the arteries, with the exception of those which give origin to deep branches; the nerves, except the sympathetic elements and the brachial plexus, to which latter the cervical sympathetic trunk is closely related.

Inset (upper right): Middle and inferior cervical sympathetic ganglia, stellate ganglion (at arrow), first and second thoracic ganglia and the communicating rami (at *). In this specimen there occurred partial fusion of the inferior cervical and first thoracic ganglia, a portion of each of these contributing to the bulk of the stellate ganglion (at arrow). The ansa subclavia passed between cranial and caudal parts of the inferior ganglion. (From Jamieson, Smith and Anson: Quart. Bull., Northwestern Univ. M. School, 26. 219-27, 1952.)

musculo-aponeurotic layer which clothes the anterior surface of the vertebral column. Its surgical significance centers in the resistant prevertebral fascia and its relation to the inferior thyroid and vertebral arteries, the phrenic nerve and the sympathetic gangliated chain. The region extends laterally to the apices of the cervical transverse processes.

SYMPATHETIC GANGLIATED CHAIN. The sympathetic gangliated chain in the neck is a prolongation of the thoracic sympathetic system, extending along the great vessels of the neck to the base of the skull (Figs. 190 to 192). The cervical chain incorporates the superior, middle and inferior ganglia, and plays an important role in pathologic changes when there is alteration of its powerful vasomotor action on the vessels to which it distributes plexuses. Section of the trunk and excision of the ganglia block the sympathetic impulses, both afferent and efferent; this is the theoretical basis for resection of the cervical sympathetic chain in exophthalmic goiter and angina pectoris.

The chain lies on the prevertebral fascia just mesial to the tuberosities of the cervical transverse processes, and is held in place by fibers derived from the underlying fascia. When the structures in the carotid sheath are retracted forward and mesially, the chain is not disturbed.

The broad, flat *superior cervical ganglion* is considered to be the coalescence of the sympathetic ganglia of the upper four cervical nerves (Fig. 192). It lies in front of the transverse processes of the first and second cervical vertebrae, and is related anteriorly to the sheath of the internal carotid artery and internal jugular vein. Inferiorly, it is connected with the middle ganglion by the sympathetic trunk. Gray communicating branches connect the superior ganglion with the upper four cervical nerves. The ganglion should not be excised unless its sympathetic communicating strand leads to the middle cervical ganglion, to prevent its being mistaken for the ganglion of the vagus. From the lower part of the ganglion is given off the superior cardiac nerve, which contributes to the formation of the cardiac plexus.

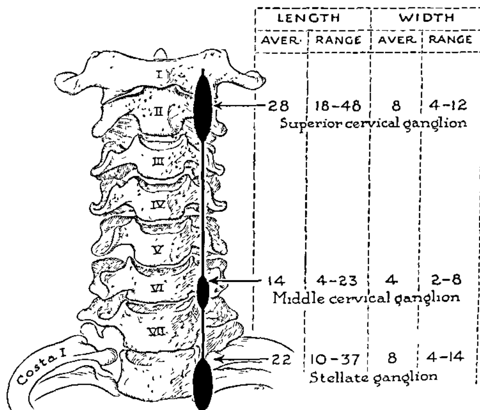


Fig. 192. CERVICAL SYMPATHETIC GANGLIA.

Each of 3 ganglia is placed at a vertebral level which represents its most frequent site in 100 body-halves. Tabular data record, in millimeters, lengths and widths (both the extremes of range and the average) for the 3 ganglionic enlargements. (From Jamieson, Smith and Anson: Quart. Bull., Northwestern Univ. M. School, 26: 219-27, 1952.)

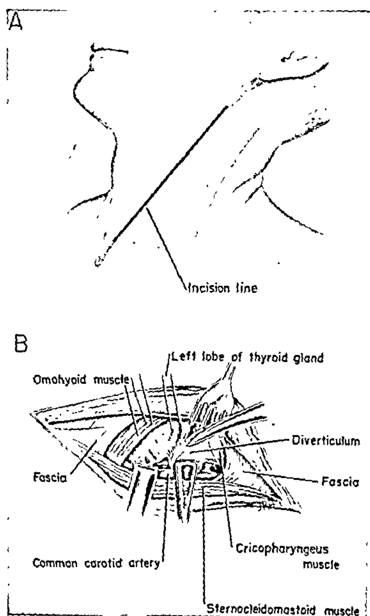


Fig. 193. CERVICAL DIVERTICULECTOMY FOR PULSION DIVERTICULUM AT THE PHARYNGO-ESOPHAGEAL JUNCTION.

A, Oblique incision at the anterior margin of the sternocleidomastoid muscle. A long transverse incision can also be used and leaves a finer scar. *B*, Detail view, the patient lying supine. Retraction gives a good exposure of the diverticulum. The left inferior thyroid vessels may be divided if they interfere with the exposure; the ansa hypoglossi nerve is sometimes in the way and may be cut without untoward effects. (From Sweet: Thoracic Surgery.)

musculo-aponeurotic layer which clothes the anterior surface of the vertebral column. Its surgical significance centers in the resistant prevertebral fascia and its relation to the inferior thyroid and vertebral arteries, the phrenic nerve and the sympathetic gangliated chain. The region extends laterally to the apices of the cervical transverse processes.

SYMPATHETIC GANGLIATED CHAIN. The sympathetic gangliated chain in the neck is a prolongation of the thoracic sympathetic system, extending along the great vessels of the neck to the base of the skull (Figs. 190 to 192). The cervical chain incorporates the superior, middle and inferior ganglia, and plays an important role in pathologic changes when there is alteration of its powerful vasomotor action on the vessels to which it distributes plexuses. Section of the trunk and excision of the ganglia block the sympathetic impulses, both afferent and efferent; this is the theoretical basis for resection of the cervical sympathetic chain in exophthalmic goiter and angina pectoris.

The chain lies on the prevertebral fascia just mesial to the tuberosities of the cervical transverse processes, and is held in place by fibers derived from the underlying fascia. When the structures in the carotid sheath are retracted forward and mesially, the chain is not disturbed.

The broad, flat *superior cervical ganglion* is considered to be the coalescence of the sympathetic ganglia of the upper four cervical nerves (Fig. 192). It lies in front of the transverse processes of the first and second cervical vertebrae, and is related anteriorly to the sheath of the internal carotid artery and internal jugular vein. Inferiorly, it is connected with the middle ganglion by the sympathetic trunk. Gray communicating branches connect the superior ganglion with the upper four cervical nerves. The ganglion should not be excised unless its sympathetic communicating strand leads to the middle cervical ganglion, to prevent its being mistaken for the ganglion of the vagus. From the lower part of the ganglion is given off the superior cardiac nerve, which contributes to the formation of the cardiac plexus.

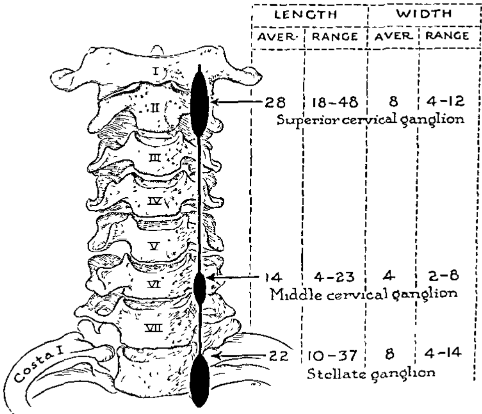


Fig. 192. CERVICAL SYMPATHETIC GANGLIA.

Each of 3 ganglia is placed at a vertebral level which represents its most frequent site in 100 body-halves. Tabular data record, in millimeters, lengths and widths (both the extremes of range and the average) for the 3 ganglionic enlargements. (From Jamieson, Smith and Anson: Quart. Bull., Northwestern Univ. M. School, 26: 219-27, 1952.)

pole of the lateral thyroid lobe. It is bound down somewhat to the prevertebral fascia and must be freed to give exposure for ligation. In front, it is covered by the carotid sheath and middle cervical ganglion; on the left, by the thoracic duct. The vertebral vessels lie posterior to it and are separated from it by the prevertebral fascia. At the point where the inferior thyroid artery turns mesially, its ascending cervical branch is given off.

Vertebral Artery. This arises from the subclavian directly or, indirectly, through the costocervical trunk as an intermediary.

In approximately 83 per cent of 400 specimens studied the vertebral artery arose directly from the subclavian (Fig. 195, *b*). In ascending, on each side of the neck, the artery, accompanied by a corresponding vein, enters a foramen in the transverse process of a cervical vertebra—most frequently that of the sixth (Fig. 196, *b*). Further ascent carries the vessel through the foramina of the upper cervical vertebrae, to the level of the atlanto-occipital membrane (Fig. 196, *a*). There, beneath the skull, each vessel inclines toward the median line; upon entering the cranial cavity by passing through the foramen magnum of the occipital bone, the two arteries join to form the basilar contribution to the *circulus arteriosus* (*Willisi*).

In a study of 350 cadavers (adult, preponderantly male) it was found that, as regularly described, the commonest site of vertebral entry was the sixth cervical vertebra (Fig. 196, *b*). The vertebral artery entered the foramen of the sixth cervical vertebra in 316 instances on the right side, in 310 on the left. Next in the order of decreasing frequency was entry at the level of the fifth cervical vertebra (right side in twenty-one cases; left side, twenty-four). Next in order were those specimens in which the vessel made entry at the level of the seventh vertebra (right side, nine instances; left side, in fourteen). Of least frequent occurrence was entry into the foramen of the fourth cervical vertebra (right half of body in four specimens; left half, in two). In no specimen did entry occur craniad to the level of the fourth cervical vertebra.

Clinically, these observations are significant in relation to angiographic demonstration of intracranial arterial aneurysms, to the proce-

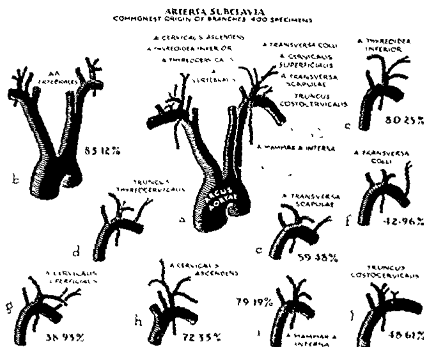


Fig. 195. MOST FREQUENT ORIGIN OF EACH OF THE BRANCHES OF THE SUBCLAVIAN ARTERY.

Other origins occur with varying frequency. For example, in the case of the vertebral artery, 5 other sites of origin were encountered in an examination of 400 specimens, the lowest frequency being 0.72 per cent. (From Daseler and Anson: Report in preparation.)

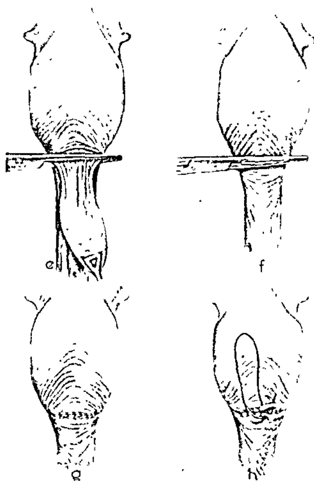


Fig. 194. METHOD OF EXCISING DIVERTICULUM AND CLOSING THE OPENING WITHOUT NARROWING THE ESOPHAGUS.

e, Forceps placed across the neck of the sac so as not to interfere with the circumference of the esophagus. *f*, Stump of amputated sac. *g*, Inner layer of interrupted fine black silk sutures. *h*, Reinforcing row of sutures. (From King: Surg., Gynec. & Obst., 85: 93–7, 1947.)

The *middle cervical ganglion*, sometimes called the thyroid ganglion, is the smallest of the cervical group, and occasionally is absent. It is located opposite the sixth cervical vertebra, usually in front of, or close to, the inferior thyroid artery. It sends gray communicating rami to the fifth and sixth cervical nerves, gives off the middle cardiac nerve, and communicates with the inferior ganglion by a well developed strand (*cf.* Figs. 190, 191).

The bean-sized *inferior cervical ganglion* is anterior to the first costovertebral joint in the angle made by the vertebral and subclavian arteries. It lies a short distance from the first thoracic sympathetic ganglion, with which it sometimes unites to form the stellate ganglion (Fig. 192). An inferior cardiac branch is given off deep to the deep cardiac plexus. Resection of the inferior cervical ganglion is a dangerous step in the removal of the gangliated chain because of its deep location and its relations to the vessels of the root of the neck (Fig. 190).

INFERIOR THYROID ARTERY. The short, thick thyrocervical trunk arises from the subclavian artery, immediately above the origin of the internal mammary artery, and terminates about 0.5 cm. from its origin (Figs. 170, 172). Its three terminal branches are the transverse cervical and transverse scapular arteries, and the inferior thyroid trunk.

The *inferior thyroid artery* ascends along the mesial margin of the anterior scalene muscle as far as the level of the cricoid cartilage. Just below the carotid tubercle the artery changes direction abruptly to run horizontally, mesially, and then downward to ramify about the lower

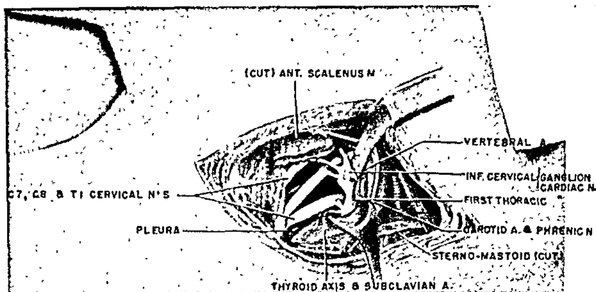


Fig. 197. ANTERIOR APPROACH TO CERVICODORSAL SYMPATHECTOMY.

The skin is cut laterally a finger's breadth above the clavicle for a distance of 5 to 7 cm. The platysma muscle, superficial jugular vein, and clavicular and sternal heads of the sternocleidomastoid muscle are divided. The omohyoid muscle may be divided. The phrenic nerve is isolated and retracted medially with the internal jugular vein. The anterior scalene muscle is transected. The lower portion of the common carotid artery and the subclavian artery are developed, bringing into view the vertebral artery and, more laterally and anteriorly, the thyroid axis. The latter is divided, and the stellate ganglion can be seen, just medial to the origin of the vertebral artery and against the seventh cervical and first thoracic vertebrae. Clearing the subclavian artery downward approaches the dome of the pleura. When Sibson's fascia is cut, the dome of the pleura is freed from the posterior aspect of the first rib. The pleura can then be separated from the ribs and vertebral bodies, and the thoracic sympathetic trunk followed down through the third ganglion. The inferior cervical ganglion and the first, second and third thoracic ganglia with the connections are usually removed.

On the left side the thoracic duct entering the subclavian vein close by the jugular vein should be protected. (From Bancroft and Pilcher: Surgical Treatment. Philadelphia, J. B. Lippincott Company.)

through an 8-cm. transverse incision placed 2 to 3 cm. above the clavicle and centered over the posterior margin of the sternocleidomastoid muscle. Skin flaps are widely dissected, and the posterior margin of the sternocleidomastoid is developed and displaced forward with the internal jugular vein. This permits recognition of the carotid tubercle landmark. The artery is found in the triangular interval between the longus colli and anterior scalene muscles, and is identified by its pulsations.

The vessel can also be reached by a presternocleidomastoid incision, identical with that used for ligation of the common carotid artery above the omohyoid muscle (p. 218). When well exposed, the carotid sheath and its contents are retracted laterally, and the carotid tubercle is found at the level of the cricoid cartilage. The artery is felt in the depths between the longus colli and anterior scalene muscles. The point of election for ligation is 1.5 cm. below the carotid tubercle.

ANTERIOR APPROACH FOR CERVICODORSAL SYMPATHECTOMY. This operation is done most commonly for relief of vasospasm in Raynaud's disease of the upper extremities, and also for severe palmar hyperhidrosis. Ochsner and DeBakey* prefer the anterior approach because a satisfactory exposure may be obtained with less operative trauma (Fig. 197). The posterior approach has some advantages (Fig. 331).

PHRENIC NERVE, AND THERAPEUTIC PARALYSIS OF THE DIAPHRAGM. Crushing, division or avulsion of the phrenic nerve to produce paralysis of the diaphragm is of considerable value in several thoracic conditions: to aid in the obliteration of the pleural space after pneumonectomy in tuberculosis, and to avoid tugging at the site of a diaphragmatic hernia repair or upon the elevated stomach after esophagectomy. If it is done during a thoracotomy, the nerve is commonly crushed with a hemostatic forceps for about 1 cm. just above the diaphragm. If permanent paralysis is desired, the crushing should be done at several levels in the upper mediastinum, midthorax,

* Ochsner, A., and DeBakey, M.: Peripheral Vascular Disease. Surg., Gynec. & Obst., 70: 1058-1072, 1940.

dure of removing a cervical herniated *nucleus pulposus*, and to that of excising a neuroma.

The vertebral artery may be successfully injected with Diodrast at the level of the fifth cervical vertebra. To accomplish this injection, the needle is caused to slip over the anterior superior margin of the process above. According to the observations already noted, the point selected would be one of safety. The procedure itself is serviceable, since, in surgical experience, aneurysm may be intracranial; the technique would aid in localizing the lesion.

Since extruded disks are not infrequent in the lower cervical region, and because the extrusion is usually posterolateral in location, the vertebral artery may be encountered. Awareness of the variability in arterial relationship should be of precautionary aid in entering the transverse foramen, to free the disk from the cervical nerve.

Similarly, in surgical removal of neuromas of the cervical nerves, it is important to remember that the vertebral artery does not invariably enter the foramen of the sixth vertebra. When freeing the nerve from the prevertebral fascia over, or near, the transverse process, the possibility of encountering the artery at a higher than "normal" level must be kept in mind (Fig. 196, *b*).

The only portion of the vertebral artery which is readily accessible at operation is that which lies between the origin and the point at which the vessel enters the vertebral foramen. In this limited area the artery is situated deep to the prevertebral fascia; it is surrounded by a plexus of sympathetic trunk. Craniad to the level of foraminous entry, the artery is covered by the heavy musculature of the neck, and would be apparent, in deep dissection, only in short segments between adjacent transverse processes of the cervical vertebrae through the foramina of which it coursed (Fig. 196, *a*).

Surgical Considerations

Ligation of the Vertebral Artery. True aneurysm of the vertebral artery is exceedingly rare; traumatic aneurysm, though rare because of the depth of the vessel, is seen more frequently. The trunk of the artery may be compressed digitally below the carotid tubercle. The most accessible approach for ligation is

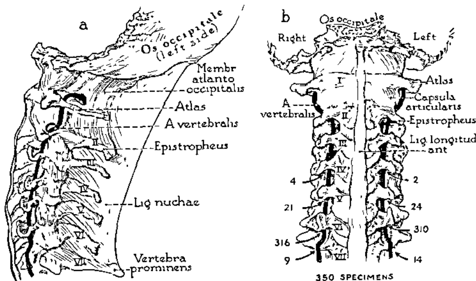


Fig. 196. COURSE OF THE VERTEBRAL ARTERY IN RELATION TO THE TRANSVERSE FORAMINA OF THE CERVICAL VERTEBRAE; LEFT LATERAL AND ANTERIOR VIEWS.

a, Typical course of the vertebral artery as it ascends from subclavian source through the foramina in the transverse processes of the cervical vertebrae (see variations in *b*). After passing through the foramen in the atlas, the artery, turning sharply medialward, pierces the atlanto-occipital membrane. Again ascending, the vessel enters the cranial cavity through the foramen magnum in the occipital bone. *b*, Demonstrating that the point of foraminous entry of the vertebral artery is variable; in 350 specimens the most frequent point of entrance, on both sides, is the sixth cervical vertebra; entrance at the level of the fourth or seventh is rare; none occurs at a level cranial to that of the fourth cervical vertebra (Adapted, with augmented data, from Bell, Swigart and Anson: Quart. Bull., Northwestern Univ. M. School, 24: 184-5, 1950.)

CHAPTER 8

Lateral Regions of the Neck

The lateral regions of the neck are the sternomastoid (carotid) and the supraclavicular.

Sternomastoid or Carotid Region

DEFINITION AND BOUNDARIES. The broad sternocleidomastoid muscle covers a wide area of the lateral region of the neck (Figs. 154 to 157). This area is known as the carotid region because the common, internal and external carotid arteries run most of their courses within it. It is limited above by the mastoid process and below by the clavicle and upper sternum; it extends in depth to the prevertebral fascia.

LANDMARKS. The *sternocleidomastoid muscle*, coursing from the mastoid process to the medial end of the clavicle, stands out in bold relief. The deep *sulcus* or *vascular groove* separating the muscle from the anterior neck regions leads superiorly to the retromandibular fossa. In thin persons the sulcus is much accentuated, particularly in the middle portion; in those with a strongly developed sternocleidomastoid the sulcus is narrowed. In the depth of the groove the great vessels of the neck may be palpated. The operative position of extension of the head puts the structures of the region on some tension, whereas flexion and rotation allow them to be palpated easily.

SUPERFICIAL STRUCTURES. Upon the surface of the sternocleidomastoid muscle the superficial vessels and nerves run in duplications of the superficial cervical fascia. The *external jugular vein* is the only vessel of any surgical consequence (Fig. 156). It is formed on the outer surface of the sternocleidomastoid muscle, inferior and posterior to the angle of the jaw, by the union of the posterior auricular vein and a branch from the posterior facial vein. Through the posterior facial vein there is an anastomosis of the external and internal jugular veins. The external jugular emerges from the inferior part of the parotid compartment and penetrates the region at the angle of the jaw. From this point it is directed downward and backward, and crosses the lateral surface of the sternocleidomastoid muscle obliquely to enter the supraclavicular fossa.

Four important superficial *branches* of the *cervical plexus* of nerves wind about the posterior margin of the sternocleidomastoid muscle (Figs. 156, 199). One of these, the great auricular, runs parallel to the external jugular vein to enter the nuchal region posterior to the ear. The cutaneous nerve of the neck crosses the muscle and supplies the region about the hyoid bone. Supraclavicular branches descend along the posterior margin of the sternocleidomastoid muscle, and the lesser occipital nerve ascends to the scalp along the same margin. These structures are covered by the platysma muscle. The *superficial lymphatics* drain to the submaxillary lymph nodes (Fig. 154).

STERNOCLEIDOMASTOID MUSCLE AND ITS ENVELOPING FASCIA. The sternocleidomastoid muscle is held securely in place by the duplication of the enveloping fascia of the neck (p. 169). The outer covering of deep fascia varies in structure. It is thick and fibrous above, where it passes over the inferior pole of the parotid gland in the retromandibular fossa, and is thin and transparent lower down.

The sternal and clavicular heads of the muscle are separated by a triangular interval, in the floor of which lies the inferior part of the carotid sheath. The sternal head may be severed and turned aside to obtain better exposure of the deeper structures. The *spinal accessory nerve* (eleventh cranial) enters the substance of the muscle about 4 cm. inferior to the tip of the mastoid process. The deep guides to the nerve are the posterior belly of the digastric muscle and the internal jugular vein, both of which the nerve crosses obliquely downward, laterally and backward (Fig. 200).

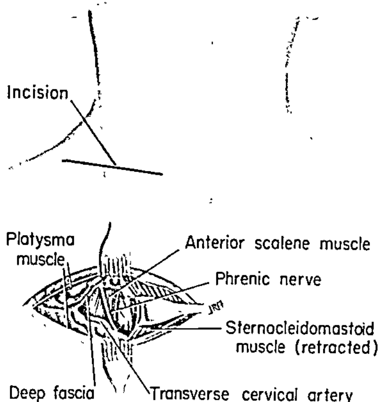


Fig. 198. SUPRACLAVICULAR PHRENICOTOMY FOR PARALYSIS OF THE DIAPHRAGM.

Local anesthesia is generally used. The 5- to 8-cm. transverse incision follows the skin lines about 2 to 3 cm. above the clavicle, and its midpoint lies at the posterior edge of the sternocleidomastoid muscle. Division of the subcutaneous fat and platysma muscle allows exposure and retraction of the sternocleidomastoid medially. Careful separation of intermuscular fat exposes the deep cervical fascia covering the anterior scalene muscle. Lying immediately beneath this membrane and directly on the anterior surface of the muscle is the phrenic nerve.

For temporary paralysis of the diaphragm the nerve is crushed with a hemostat for about 1 cm. of its length. If permanent interruption of the nerve is desired, it is avulsed, that is, the nerve is cut, and the lower end grasped with a straight hemostat and turned up for 3 to 4 cm. and cut across. The lower end drops back into the mediastinum, giving a wide separation of the ends. An accessory phrenic nerve occurs in 20 to 30 per cent of cases. *Avulsion* of the nerve removes the accessory phrenic as well as the phrenic and increases the chances of securing complete paralysis of the corresponding half of the diaphragm. (From Sweet: Thoracic Surgery.)

and close to the diaphragm. In general, barring stiffening exudate or fibrotic change, the paralyzed diaphragm rises in the chest.

When done as a procedure separate from a thoracotomy, the approach is through a low transverse supraclavicular incision (Fig. 198). The phrenic nerve is usually easily identified as it crosses the anterior scalene muscle from an oblique direction from its lateral to medial edges. If it is gently grasped with a forceps, twitching of the diaphragm and pain over the top of the shoulder are deviant. Occasionally the nerve lies along the medial border of the scalene or is embedded in the muscle itself.

rived from, the pretracheal fascia (p. 169). It is thin over the internal jugular vein, but thick and dense over the common carotid artery.

COMMON CAROTID ARTERY AND ITS RELATIONS. Usually the common carotid artery, the largest in the neck, arises from the innominate trunk on the right and from the arch of the aorta on the left (Fig. 200; *cf.* Fig. 201). It emerges from behind the sternoclavicular joint, and ascends obliquely in the direction of the angle of the mandible. At the superior margin of the thyroid cartilage, each artery, after forming a swelling known as the carotid bulb, divides into two terminal branches, the internal and external carotid arteries. These continue upward and gently diverge; the internal carotid continues in the direction of the common trunk.

The common carotid artery has posterior *relations* with the gangliated sympathetic chain, prevertebral fascia, underlying prevertebral muscles, and the anterior surface of the cervical transverse processes. The artery may be compressed easily against the bony transverse processes. The prominent carotid tubercle (p. 166) is an important landmark in the ligation of the common carotid artery (Fig. 203).

Anteriorly, the common carotid is in relation with the cellular tissue of the neck in the upper two thirds of its course, and with the pretracheal fascia in the lower third. In its middle third it is related to the omohyoid muscle, which crosses in front of the artery. That portion of the vessel below the omohyoid muscle is its surgically dangerous part, since there it has intimate relations with the great venous trunks at the base of the neck. Its course above the omohyoid, therefore, is the site of election for ligation.

INTERNAL CAROTID ARTERY. The internal carotid artery begins at the termination of the common carotid opposite the superior margin of the thyroid cartilage, and terminates in the middle fossa of the skull by dividing into the anterior and middle cerebral arteries. At its origin it lies a little posterolateral to the external carotid, but as it ascends, it passes to the mesial side of the external carotid toward the

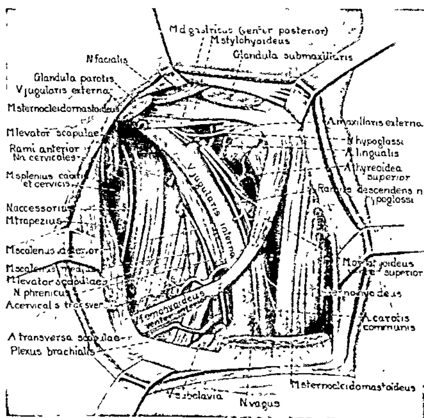


Fig. 200. STRUCTURES EXPOSED IN THE LATERAL REGION OF THE NECK WHEN THE STERNOCLEIDOMASTOID MUSCLE IS REMOVED.

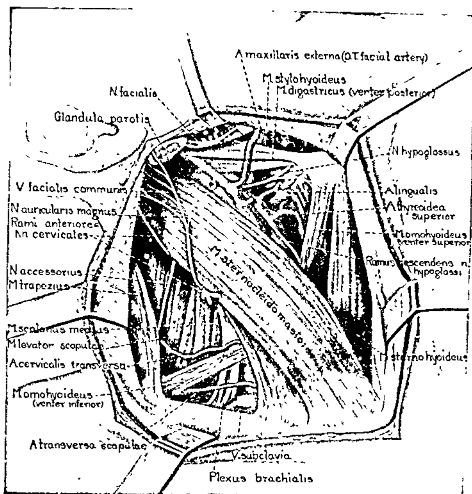


Fig. 199. STRUCTURES OF THE LATERAL REGIONS OF THE NECK, WITH THE STERNOCLEIDOMASTOID MUSCLE IN SITU.

A thin, deep fascial covering separates the muscle from the subjacent structures. Like the external layer, it is thicker and more resistant above than below. The sheath is sufficiently strong to hold fluid within it, as in a closed compartment. This fluid may be hemorrhage resulting from muscle rupture, or the contents of an abscess extending from a mastoiditis (*Bezold abscess*) (p. 97). Branchial cysts and sinuses present along the anterior border of the sternocleidomastoid muscle (p. 224).

Cervical Lymph Nodes and Their Relation to the Omohyoid Muscle and Pretracheal Fascia. When the sternocleidomastoid muscle is retracted laterally, the internal jugular vein can be distinguished in the upper half or two thirds of the exposed area, lying in an abundant meshwork of areololymphatic tissue. The lymph nodes disposed between the muscle and vein adhere more or less intimately to both structures. Adhesions caused by pathologic changes about the glands may be so dense as to require removal of the sternocleidomastoid muscle and internal jugular vein in gland dissection. After involving the lymph nodes in the submaxillary region (p. 173), carcinoma of the lip and tongue metastasizes to the *superior group* of *deep cervical lymph nodes* which lie above the omohyoid muscle. The superior group communicates below with the *inferior set* of *deep cervical nodes* which lies inferior to the omohyoid muscle and deep to the pretracheal fascia; the nodes drain toward the supraclavicular region and mediastinum (Fig. 154).

Carotid Sheath. The carotid sheath is the tubular investment of deep cervical fascia which encloses the common and internal carotid arteries, internal jugular vein, and vagus nerve. Above the common carotid artery, its structure is somewhat attenuated. The posterior wall of the sheath is adherent to the prevertebral fascia. These attachments, however, do not prevent pus from passing from the carotid compartment to the adjoining supraclavicular region. The anterior wall of the sheath fuses with, and, to some extent, is de-

side, branches of the external carotid artery supply the upper neck and extracranial soft parts of the head. At its point of election for *ligation* it lies almost in contact with the great horn of the hyoid bone, which serves as an ideal surgical landmark. In front, areologlandular tissue and the posterior belly of the digastric muscle overlie it (Fig. 200).

The *superior thyroid artery* arises from the external carotid a little above the upper margin of the thyroid cartilage. It is overlapped by the anterior margin of the sternocleidomastoid muscle, and runs downward and forward under cover of the omohyoid muscle to supply the thyroid gland. The *lingual artery* leaves the external carotid opposite the greater horn of the hyoid bone. It passes deep to the hyoglossal muscle to reach the sublingual compartment (Fig. 202). The greater horn of the hyoid bone is the surgical guide to the vessel, and the posterior belly of the digastric muscle is a guide to the depth to which the dissection has advanced. The *external maxillary (facial) artery* arises a little above the lingual artery, passes immediately upward under cover of the stylohyoid muscle and the posterior belly of the digastric, and enters the submaxillary region. The *occipital artery* is given off at the same level as the external maxillary, but from the posterior aspect of the trunk deep to the posterior belly of the digastric, and disappears under the mastoid process and its attached muscles (Fig. 227).

Collateral anastomoses between the internal and external carotid arteries are adequate to maintain circulation after ligation of either of these trunks (Fig. 203). There are many anastomotic relationships between the arteries of the ophthalmic territory of the internal carotid and the facial territory of the external carotid.

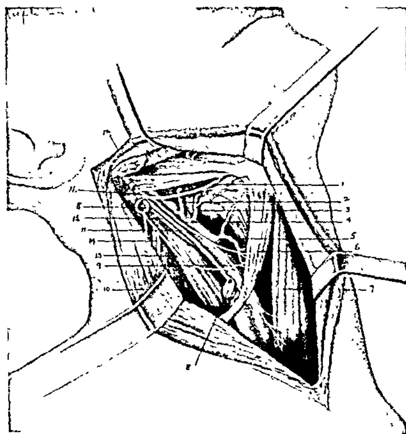


Fig. 202. UPPER STERNOCLEIDOMASTOID REGION TO SHOW THE BRANCHES OF THE EXTERNAL CAROTID ARTERY.

1, N. hypoglossus; 2, A. maxillaris externa; 3, A. lingualis; 4, ramus descendens n. hypoglossi; 5, A. thyreoidea superior; 6, M. omohyoideus; 7, M. sternohyoideus; 8, V. jugularis interna (resected); 9, A. carotis communis; 10, M. sternocleidomastoideus; 11, N. vagus; 12, glandula parotis; 13, ansa hypoglossi; 14, Nn. cervicales III et IV; 15, A. carotis interna; 16, A. carotis externa.

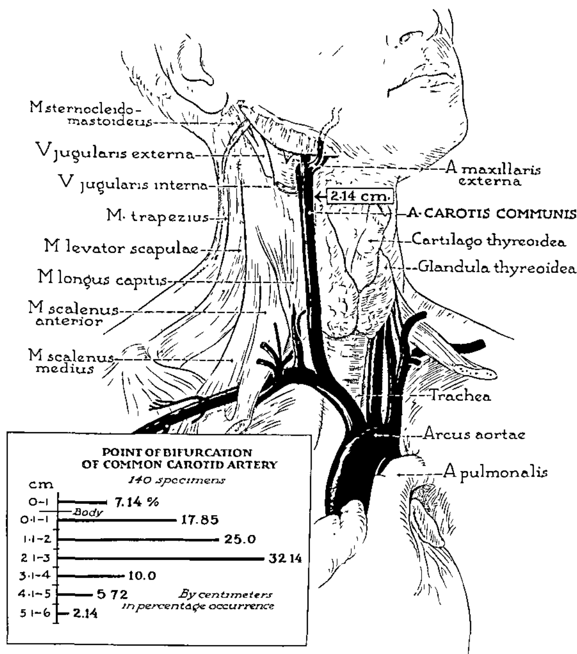


Fig. 201. COMMON CAROTID ARTERY AND BRANCHES.

Showing the origin, course and divisions of the artery, together with a graph of measurements taken from 140 cervical dissections (right and left halves combined) of the distance from the inferior border of the body of the mandible to the point of carotid bifurcation. Most frequently division takes place in a zone 2.0 to 3.0 cm. below the mandible; the average distance is 2.14 cm., as indicated by arrow on the drawing. (From McAfee, Anson and McDonald: Quart Bull., Northwestern Univ. M. School, 27: 226–9, 1953.)

lateral wall of the pharynx (Fig. 202). When it reaches the pharynx, the artery runs vertically into the maxillopharyngeal space.

EXTERNAL CAROTID ARTERY AND ITS BRANCHES WITHIN THE REGION. The external carotid artery arises from the common carotid opposite the upper border of the thyroid cartilage, somewhat mesial to, and in front of, the internal carotid artery. It then is directed upward and backward to the angle of the jaw. Here it changes direction and rises vertically to engage under the stylohyoid muscle and the posterior belly of the digastric; it reaches the posteromesial surface of the parotid gland (p. 119). It continues upward through the gland just behind the neck of the mandible, where it ends by dividing into the internal maxillary and superficial temporal arteries. On either

side, branches of the external carotid artery supply the upper neck and extracranial soft parts of the head. At its point of election for *ligation* it lies almost in contact with the great horn of the hyoid bone, which serves as an ideal surgical landmark. In front, areologlandular tissue and the posterior belly of the digastric muscle overlie it (Fig. 200).

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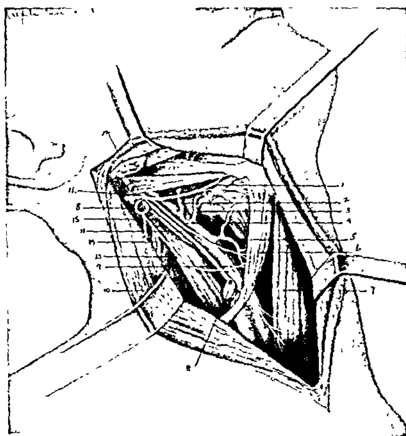


Fig. 202. UPPER STERNOCLEIDOMASTOID REGION TO SHOW THE BRANCHES OF THE EXTERNAL CAROTID ARTERY.

1, N. hypoglossus; 2, A. maxillaris externa; 3, A. lingualis; 4, ramus descendens n. hypoglossi; 5, A. thyreoidea superior; 6, M. omohyoideus; 7, M. sternohyoideus; 8, V. jugularis interna (resected); 9, A. carotis communis; 10, M. sternocleidomastoideus; 11, N. vagus; 12, glandula parotis; 13, ansa hypoglossi; 14, Nn. cervicales III et IV; 15, A. carotis interna; 16, A. carotis externa.

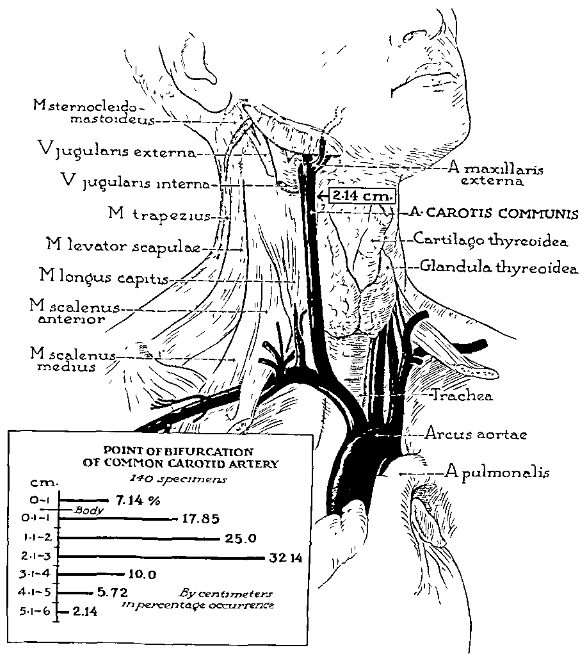


Fig. 201. COMMON CAROTID ARTERY AND BRANCHES.

Showing the origin, course and divisions of the artery, together with a graph of measurements taken from 140 cervical dissections (right and left halves combined) of the distance from the inferior border of the body of the mandible to the point of carotid bifurcation. Most frequently division takes place in a zone 2.0 to 3.0 cm. below the mandible; the average distance is 2.14 cm., as indicated by arrow on the drawing. (From McAfee, Anson and McDonald: Quart. Bull., Northwestern Univ. M. School, 27: 226–9, 1953.)

lateral wall of the pharynx (Fig. 202). When it reaches the pharynx, the artery runs vertically into the maxillopharyngeal space.

External Carotid Artery and Its Branches within the Region. The external carotid artery arises from the common carotid opposite the upper border of the thyroid cartilage, somewhat mesial to, and in front of, the internal carotid artery. It then is directed upward and backward to the angle of the jaw. Here it changes direction and rises vertically to engage under the stylohyoid muscle and the posterior belly of the digastric; it reaches the posteromesial surface of the parotid gland (p. 119). It continues upward through the gland just behind the neck of the mandible, where it ends by dividing into the internal maxillary and superficial temporal arteries. On either

either anatomically or clinically, unless the anastomotic paths are disturbed.

Internal Jugular Vein and Its Common Facial Branch. The *internal jugular vein* is the principal venous trunk of the neck and is the direct downward continuation of the transverse (lateral) sinus. The vessel rarely is seen surgically in its upper portion, which lies deep to the styloid process and to the parotid compartment. It descends in the carotid sheath, and may be recognized easily by its bluish-gray color. The internal jugular vein runs to a point a little lateral to the sternoclavicular joint, where it unites with the subclavian to form the innominate vein. As it descends, it increases gradually in size upon receiving various tributaries (Fig. 200).

The internal jugular is the largest of the relatively superficial veins of the body, and may be involved in piercing wounds. This vessel and the carotid artery usually escape injury in suicidal wounds, since the position assumed, with the chin tilted back and the sternocleidomastoid muscle made tense, protects them. The vein is influenced greatly by respiration, emptying during inspiration and filling during expiration, so that the thin-walled tube may be distended to 1.5 cm. in diameter, or be a flaccid, ribbon-like structure with its walls in contact. During inspiration, air may be drawn into a rent in the vein and may embarrass respiration seriously by the formation of air emboli in the pulmonary veins, or cause death if sufficient air reaches the heart. The vein may be infected secondarily after intracranial sinus thrombosis, particularly that involving the transverse sinus. Infection is accompanied by pain and tenderness along the course of the vein.

The *common facial vein* (p. 173) is the most important contributing branch to the internal jugular. The trunk is formed about the submaxillary gland by the union of the anterior and posterior facial veins. It passes backward and downward to pierce the carotid sheath and enter the internal jugular vein opposite the great horn of the hyoid bone. It receives the thyroid and lingual veins and might be termed the "thyro-lingual-facial" trunk. The common facial vein, which often is joined by the anterior jugular vein, is a source of embarrassment in operations for lymph node resection in the retromandibular area. The superior thyroid vein may enter the internal jugular directly, as do the middle thyroid veins (Fig. 199).

Vagus Nerve. The vagus nerve lies between the internal jugular vein and the internal and common carotid arteries, and passes through the neck to its terminations in the thorax and abdomen (Fig. 200). Injury to the nerve in ligation of the vessels is of serious consequence. The superior laryngeal branch is given off behind the carotid and traverses the thyrohyoid membrane with the superior laryngeal vessels. The inferior laryngeal nerve is the recurrent vagus branch from within the thorax.

Thoracic Duct. As it leaves the thorax, the thoracic duct is applied closely to the left side of the esophagus. The duct ascends in the neck about 4 cm. above the clavicle, and turns laterally behind the carotid sheath and in front of the inferior thyroid and vertebral arteries. At the medial margin of the anterior scalene muscle it drops down to enter the angle of union of the internal jugular and subclavian veins. It drains the lymph from both lower extremities, the abdominal walls, most of the abdominal viscera, and the left half of the thorax (Figs. 204, 326). Near its opening, it usually is joined by the collecting lymphatic trunks from the left upper extremity and the left side of the head and neck.

Retromandibular Fossa. The retromandibular fossa is a boundary region between the neck and head, and, from the surgical viewpoint, is allied closely with the structures in the submaxillary compartment (p. 172). It is in vital connection with the structures of the sternomastoid region. The fossa is bounded in front by the posterior margin of the ramus of the mandible, and behind by the anterior border of the sternocleidomastoid muscle, and contains much of the posterior bellies of the digastric and stylohyoid muscles, deep to which lies the trunk of the external carotid artery. Into the region passes the facial nerve (seventh cranial), which emerges from the skull through the stylomastoid foramen and runs forward between the laminae of the parotid gland. An important content of the space is that portion of the parotid gland lying below the mandible (Fig. 199).

Hypoglossal Nerve. The hypoglossal (twelfth cranial) or motor nerve to the tongue is an occupant of this region only in its proximal portion, where it lies deep to the parotid gland and descends between the internal carotid artery and the internal jugular vein. It appears beneath the lower margin of the posterior belly of the digastric muscle and turns

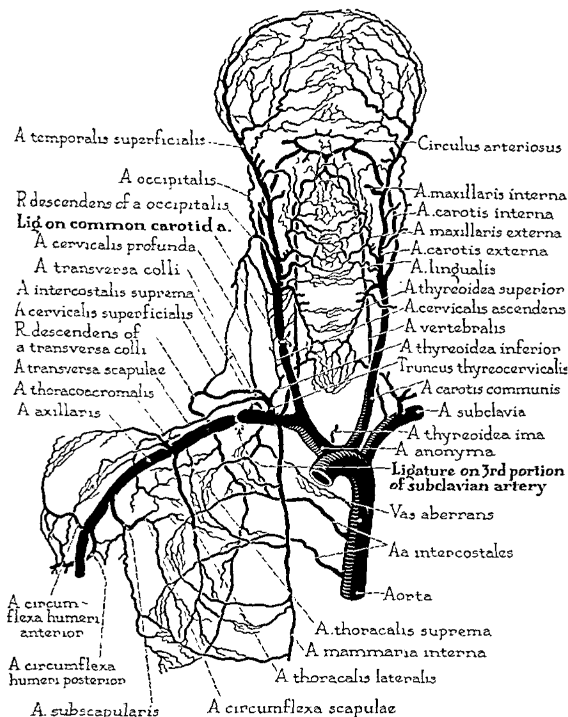


Fig. 203. CHANNELS OF COLLATERAL CIRCULATION IN THE HEAD, NECK AND THORAX.

(Adapted from Deaver.)

There is an efficient anastomotic communication between the external carotid artery and the thyrocervical trunk through the superior thyroid branch of the former and the inferior thyroid branch of the latter. Free communication is present between the vertebral and internal carotid arteries by the posterior communicating artery of the circle of Willis. Numerous unions between the lingual, facial, occipital, posterior auricular and ascending pharyngeal arteries, which make vast peribuccal and peripharyngeal circles, connect the external carotid arteries of the two sides. One internal carotid artery indirectly communicates with the other across the base of the brain by the anterior communicating artery and with the basilar trunk. Ordinarily, ligation of the common carotid artery does not stop the circulation,

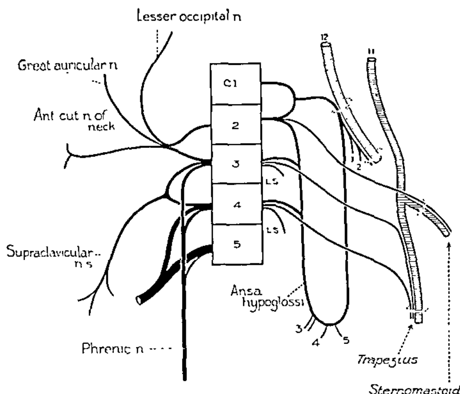


Fig. 205. CERVICAL PLEXUS; SCHEMATIC.

Showing the relations of branches of the plexus to the hypoglossal nerve (12) and the spinal accessory nerve (11). The branches of the ansa hypoglossi to the following muscles are indicated by numbers: 1, thyrohyoid; 2, geniohyoid; 3, omohyoid; 4, sternothyroid; 5, sternohyoid. *Branches from the third and fourth segments to the levator scapulae are indicated by L.S.* (From Haymaker and Woodhall: Peripheral Nerve Injuries.)

forward almost at a right angle. After crossing the external and internal carotid arteries and continuing forward a little above the level of the hyoid bone, it disappears under the posterior belly of the digastric and reappears within the submaxillary compartment, lying on the hyoglossus muscle (p. 173). It enters the intermuscular cleft between the hyoglossus and mylohyoid muscles to reach the muscles of the tongue (Fig. 159).

CERVICAL PLEXUS. The cervical plexus is formed by the anterior rami of the first four cervical nerves (Fig. 205), and each nerve receives a gray ramus communicans from the superior cervical sympathetic ganglion. These nerves are combined in an irregular series of loops under cover of the sternocleidomastoid muscle, deep to the longus capitis muscle, and on the scalenus medius. The roots of the plexus lie deep to the prevertebral fascia, and are free from injury in radical removal of the glands of the neck. The terminal branches pierce the fascia to go to the muscles they supply and the nerves with which they communicate.

The *superficial cutaneous branches* radiate from the plexus and appear in the supraclavicular region by winding about the posterior margin of the sternocleidomastoid muscle (Fig. 156). Of the *muscular* or *deep branches*, the phrenic nerve is the most important. It is derived mainly from the fourth cervical, reinforced by roots from the third and fifth cervical nerves, and passes downward in the neck deep to the prevertebral fascia. It runs on the anterior scalene muscle and enters the thorax at the root of the neck (Fig. 197), to be distributed to the diaphragm.

Surgical Considerations

EXCISION OF DEEP CERVICAL LYMPH NODES. A block dissection of lymphatic-bearing tissue of the neck offers the only chance of curing metastatic carcinoma in that area. The primary carcinoma usually arises in the lip, tongue, alveolus, floor of the mouth or on the buccal mucosa. Central lesions tend to spread to both sides of the superficial or "suprahyoid" nodes, while those on the sides or farther back in the

Fig. 204. AZYGOS AND ASCENDING LUMBAR VEINS, THEIR TRIBUTARIES AND RELATED STRUCTURES, FROM PELVIC TO CERVICAL LEVEL.

a, In the thorax and abdomen the intercostal and lumbar tributaries of the azygos system are seen, together with related arteries and nerves, the ganglionated sympathetic trunk and the thoracic duct. In the abdominal region the kidney and adrenal gland are shown, together with their vessels of supply. Several lumbar veins are shown, as well as the ascending lumbar vein, through which latter, as an intermediary, they communicate with the left common iliac vein. *b*, The left kidney, with the adrenal gland, has been rolled to the opposite side of the trunk on its vascular pedicle; the abdominal aorta has been retracted in order to expose components of the prevertebral plexus of veins. At second lumbar level the visceral (renal) and parietal (ascending lumbar) veins are brought into communication (at *). *c*, The aortic arch has been drawn downward and to the right, in order to demonstrate its intercostal and related branches and the corresponding veins. The stump of the left subclavian vein has been lifted, showing the termination, therein, of the thoracic duct. (From Davis, Milloy and Anson: Surg., Gynec. & Obst., in press.)

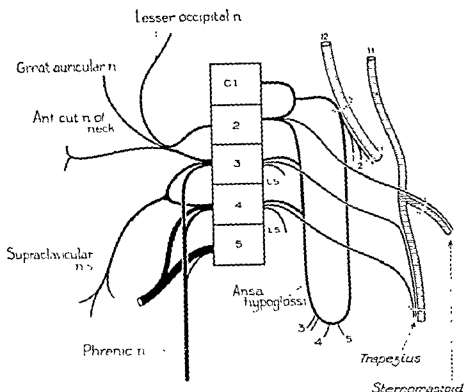


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mouth structures are apt to extend unilaterally to the deep superior cervical nodes and then down the internal jugular chain. As indicated to meet the various situations, a bilateral suprahyoid (Fig. 161) or complete unilateral neck dissection is done. Occasionally, with the latter on one side, the upper dissection on the other side is done to remove involved areas; at times a bilateral complete dissection has been done in two stages. These dissections carry a low operative mortality rate and should be done early, when local lesions are controllable, and not as last-resort measures (Figs. 206 to 211).

LIGATION OF THE COMMON CAROTID ARTERY. This vessel may require ligation to control profuse hemorrhage from deep wounds in the upper part of the neck, or from large, malignant and/or ulcerative lesions of the neck, face or throat. Ligation may also be done as a preparation for the removal of tumors or for the interruption of circulation through an aneurysmal sac. The pathways of collateral circulation are extensive (Fig. 203), but cerebral softening, hemiplegia or death follows common or internal carotid ligation in about 25 per cent of cases. A short period of pressure on the carotid, applied several times a day for two to three weeks preoperatively, may build up collaterals and obviate cerebral changes at the time of the ligation.

The vessel may be ligated above or below the omohyoid muscle, but the site of election is *above the omohyoid crossing* (Fig. 211). The skin incision, about 7 to 8 cm. long, is centered transversely over the sternocleidomastoid muscle just below its midportion (Fig. 160). After the superficial structures have been divided the enveloping fascia is incised along the anterior

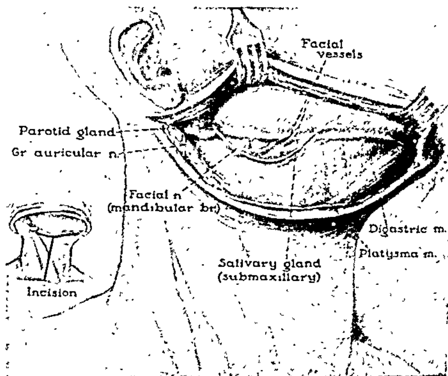


Fig. 206. RADICAL NECK DISSECTION.

A suprahyoid incision with a T extension to the clavicle (inset) is used. The horizontal portion of the incision is first made about 1.5 cm. below the inferior border of the mandible and is carried through the skin, subcutaneous tissue and platysma muscle down to the enveloping layer of the deep cervical fascia. Unless the submaxillary lymph nodes are involved with metastatic growths, the marginal mandibular branch of the facial nerve is located near the posterior facial vein (Figs. 131, 132) and carefully spared in order to avoid a disfiguring deformity to the lower lip (Fig. 130). If looked for anteriorly, the nerve courses near the inferior border of the mandible and roughly parallel to it. It lies beneath the upper part of the platysma, but superficial to both the anterior facial vein and the external maxillary artery. The anterior facial vein is the best anterior landmark for locating this important branch of the facial nerve, for with careful dissection the vein can be seen shining through the surrounding connective tissue, and the marginal branch of the facial nerve passes immediately superficial to it. The nerve is then traced backward to its emergence from the parotid gland. About 1 cm. posterior to the angle of the mandible the cervical branch of the facial nerve descends to the deep surface of the platysma. It may be cut with impunity. (From Beahrs, Gossel and Hollinshead: Am. J. Surg., 90: 490-516, 1955.)

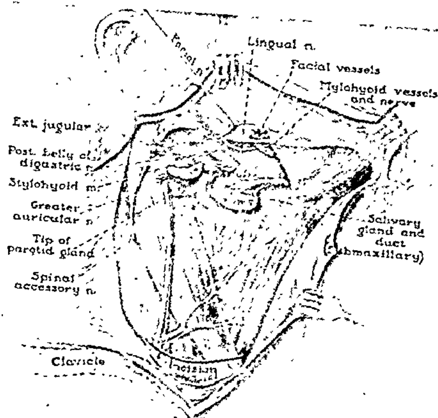


Fig. 207. RADICAL NECK DISSECTION (CONTINUED).

The tissues at the lower border of the mandible are divided and retracted downward. In doing this, the facial artery and vein are ligated above the lower border of the mandible, and the attachment of the deep cervical fascia to the mandible is cut. The incision is carried backward, and the lower pole of the parotid gland is divided to facilitate visualization of the upper end of the internal jugular vein. In doing this, the previously exposed marginal mandibular branch of the facial nerve is carefully spared. Fistulas never develop after transection of the lower pole of the parotid gland. Before transecting the latter, the external jugular vein is identified high up, ligated and divided, and the near-by great auricular nerve is sectioned. On completion of this horizontal portion of the incision, the wound is packed with gauze, and attention is turned to the vertical incision.

The vertical incision is made from the midpoint of the upper horizontal incision straight downward to a point on the clavicle between the sternal and clavicular heads of the sternocleidomastoid muscle. Anterior and posterior flaps of skin, subcutaneous tissue and platysma are developed. The line of section of the sternocleidomastoid muscle and lower end of the internal jugular vein is shown. (From Beahrs, Gossel and Hollinshead: Am. J. Surg., 90: 490–516, 1955.)

margin of the sternocleidomastoid muscle. When the muscle is retracted posteriorly, the omohyoid muscle is seen in the lower angle of the wound and is drawn downward and inward, or is divided. The descending hypoglossal nerve is carried laterally, and the thyroid gland may have to be drawn mesially. The artery is located, and ligatures are passed around it from without inward to minimize the possibility of including the vagus nerve.

For ligation below the omohyoid crossing, the transverse incision is made more anteriorly and 3 cm. below (Fig. 160). The anterior jugular vein may require division. The enveloping fascia is divided, and the sternocleidomastoid muscle is drawn backward. The three flat infrahyoid muscles, clothed in pretracheal fascia, are exposed, and the sternohyoid and sternothyroid muscles are drawn mesially and inferiorly. The omohyoid muscle is retracted laterally or is cut, as occasion demands. The lateral lobe of the thyroid gland conceals the carotid sheath and must be retracted mesially. On the left side the internal jugular vein tends to overlie the artery; consequently the common carotid lies deeper in the root of the neck, making the operation more difficult.

Ligation of External Carotid Artery. This may be done for injury to this vessel or its branches, for reducing hemorrhage in the more extensive operations on the face or neck —such as excision of the upper or lower jaw

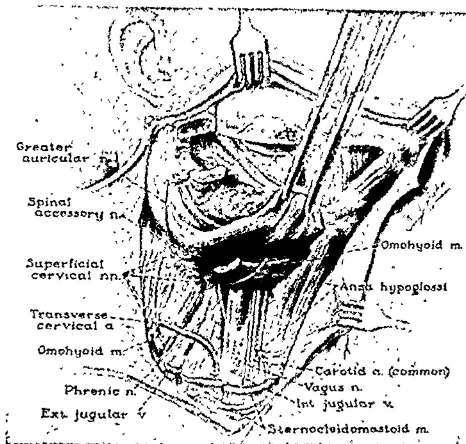


Fig. 208. RADICAL NECK DISSECTION (CONTINUED).

In transecting the lower attachments of the sternocleidomastoid muscle 2.5 cm. above the clavicle, the fascia enveloping the muscle is incised at its anterior and posterior borders. Through the anterior incision a finger is passed behind the muscle, but inside its fascia. In this way, on incising the muscle, the structures in the carotid sheath (internal jugular vein, common carotid artery and vagus nerve) and the phrenic nerve are protected from injury.

The next part of the dissection concerns the structures of the posterior triangle of the neck. The fatty-areolar tissue which contains the lymph nodes in this triangle lies between the anterior and posterior layers of the deep fascia and is dissected free from the latter. Beginning along the posterior border of the sternocleidomastoid muscle, the external jugular vein is uncovered, followed downward, ligated and divided as close as possible to the subclavian vein. The omohyoid muscle is next developed as it emerges from beneath the posterior edge of the sternocleidomastoid muscle, and the muscle is pushed upward and divided as low as possible. Transverse cervical and transverse scapular veins are also ligated and cut. In order to free the base of the block in the posterior triangle, the dissection is carried anteriorly to the level of the carotid sheath. About this area and behind the posterior layer of the deep fascia, and therefore not disturbed by the dissection, are the nerves to the rhomboids and the serratus, the brachial plexus between the middle and the anterior scalene muscles, the subclavian vessels and their branches and the phrenic nerve. The last is usually spared, but may be sacrificed if necessary to do a better operation for a malignant growth.

After the base of the posterior triangle has been cleared out the fatty-areolar tissue along the anterior border of the trapezius is divided, and the dissection proceeds upward. The spinal accessory nerve is encountered as it passes deep to the anterior border of the trapezius and is divided (some surgeons spare this nerve).

Next begins dissection deep to the sternocleidomastoid. Transection of the lower end of the internal jugular vein starts by splitting the anterior wall of the carotid sheath at a low level transversely, isolating the vein, clamping and ligating it low down. Posterolateral to the vein is a mass of areolar tissue containing lymph nodes, and near the lower end are the thoracic duct on the left and the right lymphatic duct on the right. These should be spared as the internal jugular vein and its surrounding fatty-areolar tissue are dissected upward and separated from the other carotid sheath structures. If the thoracic duct is injured, it should be ligated to prevent leakage. The ansa hypoglossi nerve usually comes into view on or embedded in the carotid sheath. Transverse scapular and transverse cervical arteries encountered are ligated and divided. Anterior cutaneous nerves are also exposed and divided in order to free the block. This and the division of the great auricular nerve account for the numbness in the region of the ear and neck following a radical neck dissection. Neuromas developing from these sensory nerves occasionally cause severe pain in this region. (From Beahrs, Gossel and Hollinshead: Am. J. Surg., 90: 490–516, 1955.)

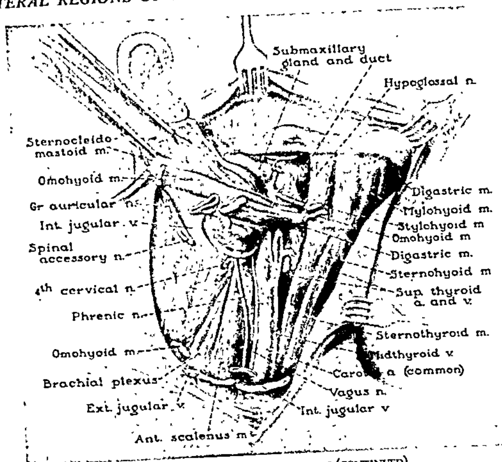


Fig. 209. RADICAL NECK DISSECTION (CONTINUED).

In the upward portion of the anterior triangle dissection a number of tributaries of the internal jugular, including the common facial and, in various combinations, the superior thyroid, lingual, pharyngeal and laryngeal veins, are encountered, ligated and divided. The external branch of the superior laryngeal nerve (to the cricothyroid muscle) lies close to the superior thyroid artery and should be avoided in any case. Except at their upper ends both the superior thyroid artery and vein are largely under cover of the strap muscles of the neck in their course to the thyroid gland. The anterior belly of the omohyoid muscle is stripped to the hyoid bone, from which it is freed with the block of tissue which up to this stage of the dissection contains not only the nodes of the posterior triangle (the transverse cervical chain, the spinal accessory group of nodes and the subfascial occipital node), but also the deep cervical nodes associated with the internal jugular lymphatic chain. The dissection up to this point has included these nodes up to about the level of the posterior belly of the digastric muscle. The further dissection removes the uppermost members of the chain and the submaxillary and submental nodes. (From Beahrs, Gossel and Hollinshead: Am. J Surg., 90: 490–516, 1955.)

for carcinoma, or the removal of large malignant growths from the pharyngeal wall, parotid gland, or tongue. Collateral circulation after ligation is adequate by anastomoses with branches from the opposite external carotid (Fig. 203).

The site of election for ligation is between the emergence of the superior thyroid and lingual vessels (Fig. 160), but ligation may be performed proximal to the origin of the superior thyroid. A 6- to 8-cm. transverse incision is made over the sternocleidomastoid muscle, just above its midpoint. After division of the superficial structures and enveloping fascia, the anterior margin of the sternocleidomastoid muscle is freed and is retracted posteriorly. The inferior pole of the parotid gland may have to be retracted gently upward to expose the digastric tendon and the arching loop of the hypoglossal nerve, which cross the artery at this level. The ligature should be applied at about the level of the greater horn of the hyoid bone, which is the surgical landmark. The greatest embarrassment comes from the overlying thyroid, lingual and facial branches of the common facial vein, which require retraction or division. Care is taken to avoid the superior laryngeal nerve lying behind the artery.

LIGATION OF THE INTERNAL CAROTID ARTERY. The internal carotid trunk contributes

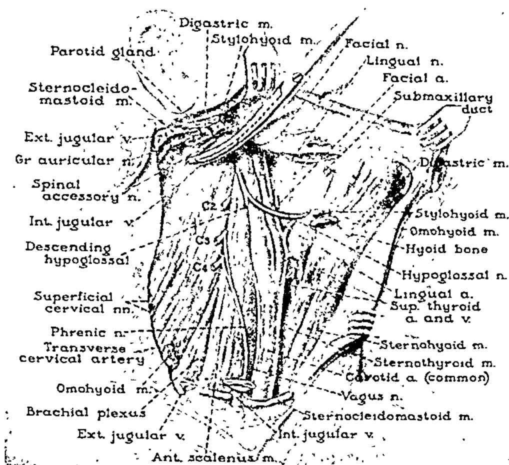


Fig. 210. RADICAL NECK DISSECTION (CONCLUDED).

☞ The region of the posterior belly of the digastric is one of especially complicated anatomy and must have careful attention. Branches of the external carotid artery which course posteriorly across the internal jugular vein and therefore must be ligated are the sternocleidomastoid branch of the superior thyroid artery, the occipital artery and its sternocleidomastoid branch and sometimes the posterior auricular artery. The hypoglossal nerve lies under the posterior belly of the digastric as it runs forward above the greater corner of the hyoid bone. It gives off its thyrohyoid branch and then disappears beneath the posterior belly of the digastric and the stylohyoid muscles to enter the submaxillary triangle. This nerve must be spared.

Dissection of the submental triangle is begun by splitting the fascia covering the mylohyoid muscle from the hyoid bone to the symphysis of the mandible, and the anterior belly of the digastric is cut from the mandible. The deep fascia covering the triangle and all the connective tissue down to the mylohyoid muscle are stripped from the muscle, the deep fascia being detached below from the hyoid bone. Through this procedure the submental lymph nodes are removed. The mylohyoid muscle is disturbed as little as possible. The fascial attachments of the digastric tendon to the hyoid bone are freed, and the stylohyoid muscle is likewise detached. Anterior retraction on the posterior border of the mylohyoid muscle reveals the lingual nerve above, the hypoglossal nerve below and the submaxillary duct running between the two. The lingual nerve is separated from the submaxillary duct and surrounding tissue, and the duct is ligated and divided. The submaxillary ganglion, seen suspended from the lingual nerve, lies on the hypoglossus muscle and should be spared if possible. The hypoglossal nerve is located in the hyoglossus muscle and is carefully spared. The lingual artery passes on the under surface of this muscle, and it is here that the hyoglossal nerve and the 2 bellies of the digastric form Lesser's triangle.

As the submaxillary gland with the tissues associated with it are freed, it will be found held on its deep surface by the external maxillary or facial artery. This is divided once again to allow removal of the submaxillary gland.

Attention is transferred to the upper and posterior portion of the block, where the sternocleidomastoid muscle and the posterior belly of the digastric are detached from the mastoid process. Bleeding vessels encountered here are branches of the posterior auricular and occipital arteries and veins. The stylohyoid muscle is now transected at its origin on the styloid process. The specimen is alternately put on anterior, upward and posterior traction as the tissues binding it down are freed. The spinal accessory nerve lying on or close to the internal jugular vein is sectioned high, and the vein is clamped as high as possible and cut, and the upper end ligated. With the ligation of a few additional bleeding veins the dissection is complete, and the block mass tissue can be removed. (From Beahrs, Gossel and Hollinshead: Am. J. Surg., 90: 490–516, 1955.)

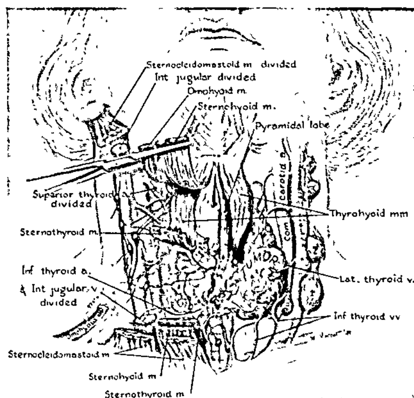


Fig. 211. CARCINOMA OF THE LEFT LOBE OF THE THYROID, WITH DEEP CERVICAL LYMPH NODE INVOLVEMENT.

This is an unusual but interesting case requiring excision of the thyroid and left radical lymph node dissection. The lymph nodes marked 3, 4 and 5 were involved with carcinoma. Nodules previously removed at 1 and 2 were diagnosed as papillary carcinoma of aberrant thyroid tissue. (From Ward, Hendrick and Chambers: Ann. Surg., 131: 473–93, 1950.)

to the formation of the arterial circle at the base of the brain. Its middle cerebral branch has been emphasized (p. 26), and its main trunk has important pharyngeal and tonsillar relations (p. 156). Its relation to the cavernous sinus and ophthalmic artery is of prime importance (p. 18). The cervical part of the artery is accessible through the same incision used for exposure of the external carotid artery (Fig. 160).

The internal carotid artery is seldom ligated. The procedure carries with it a greater risk of cerebral softening, hemiplegia and death than ligation of the common carotid artery, and the latter is more accessible.

Exposure and Ligation of the Internal Jugular Vein. Ligation of the internal jugular vein occasionally has been resorted to in transverse sinus thrombosis (p. 17) to prevent propagation of infection through the internal jugular to the general circulation. The vein may be found readily through a low transverse incision (Fig. 160) and forward displacement of the sternocleidomastoid muscle. In its lower portion the vein is isolated easily; in its upper part it is ligated with difficulty because of its many tributaries. The ligation of one internal jugular vein can be done with impunity, and even bilateral ligation usually is tolerated well.

Aneurysm of the Common Carotid Artery. Aneurysm may develop in any part of the course of the common carotid artery. The usual locations are at the origin from the innominate artery on the right; at the origin from the aortic arch on the left; and at the level of bifurcation into external and internal branches. A carotid aneurysm usually is small, and the long axis lies parallel with that of the vessel.

On the medial side the trachea, larynx, pharynx and esophagus are compressed, obstructed and displaced, and afford locations for the rupture of aneurysm. The vagus, phrenic, sympathetic and recurrent laryngeal nerves and the internal jugular vein may become blended with the carotid sheath and eventually with the aneurysmal sac, a complication contributing to the difficulties of extirpation or even ligation.

Branchial Cysts, Sinuses and Fistulae. Early in embryonic life, entodermal pouches pocket out from the pharynx. Simultaneously,

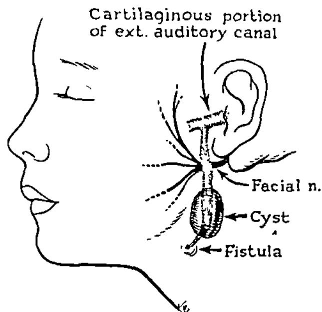


Fig. 212. CYST AND FISTULA DERIVED FROM THE FIRST BRANCHIAL CLEFT.

This may extend as high as the external acoustic meatus. Experience has shown that the tract lies on the lateral aspect of the facial nerve; consequently the surgical approach must be careful in order to avoid injury to the nerve. Cyst, sinus and fistulous tracts are derived more frequently from the second branchial cleft than from the first (Fig. 177). (From Bill: S. Clin. North America, 36: 1599-1611, 1956.)

the cervical ectoderm becomes indented (branchial grooves or clefts) over the corresponding pharyngeal pouches. As the grooves approach the pouches, the intervening mesoderm is pushed aside, so that for a time the ectoderm and the entoderm are in contact. The areas in contact are the closing membranes. The series of rounded bars of mesoderm, which are pushed aside as the clefts and pouches are approximated, are the branchial arches. In gill-bearing animals the closing membranes disappear, resulting in a series of gill clefts, opening from the pharynx to the exterior. Figures 177, 186 and 187 designate the branchial clefts, pouches and arches and their ultimate derivatives.

Sinuses with external and internal openings, cysts with no internal or external openings, and fistulous tracts with external and internal openings, and dermoids are the vestigial branchial derivatives found in the sternomastoid area (Fig. 212).

Clinically, a branchial cyst, unless secondarily infected, is a painless, fluctuant tumor located characteristically at any level in the neck along the anterior margin of the sternocleidomastoid muscle. The cyst extends under it to the deeper structures. Only complete surgical removal under general anesthesia will effect a cure. A satisfactory exposure of the cyst, sinus or fistula can be obtained through a transverse incision at the proper level (Fig. 160). Injection of methylene blue helps greatly to locate the extent of the process.

Operative Injury to the Spinal Accessory Nerve in the Posterior Cervical Triangle. The superficial course of the spinal accessory



Fig. 213. DEFORMITY DUE TO RIGHT SPINAL ACCESSORY NERVE INJURY IN THE POSTERIOR CERVICAL TRIANGLE.

Posterior view shows atrophy of the superior third of the right trapezius muscle and inability to abduct the arm above 90 degrees. (From Woodhall: Arch. Surg., 74: 122-7, 1957.)

nerve (Fig. 200) in the posterior cervical triangle makes it peculiarly susceptible to injury. This may be part of a planned procedure for metastatic carcinoma in cervical lymph nodes and is then a calculated risk (Fig. 209). Injury, however, may occur inadvertently during lymph node biopsies, removal of minor tumor masses or other operative procedures in this area. Resulting paralysis of the trapezius muscle causes loss of true abduction of the arm above 80 or 90 degrees (Fig. 213) and diffuse shoulder girdle discomfort.

In the performance of the positive abduction test for spinal accessory nerve paralysis the examiner holds the wrist firmly at the side. The patient then attempts abduction against the fixed point of resistance. A positive test indicating an accessory nerve lesion with trapezius muscle paralysis is shown by flaring of the entire vertebral border of the scapula and virtual dislocation of the scapula laterally upon the thoracic cage.

Operative dissection of the injured site and resuture of the nerve restore normal function.*

Supraclavicular Region or Fossa, or Posterior Cervical Triangle

Definition, Boundaries and Superficial Structures. The supraclavicular fossa, or posterior cervical triangle, is a depressible space above the middle third of the clavicle (Fig. 199); its base rests upon the dome of the pleura. It corresponds to the area embraced by the posterior margin of the sternocleidomastoid muscle, the middle third of the clavicle, and the anterior edge of the trapezius. Its width and depth vary with the muscular development of the person. The fossa is in broad communication with the sternomastoid, mediastinal and axillary regions, which may be invaded by infections or tumors originating supraclavicularly. The upper part of the area is exposed in the removal of the superior group of deep cervical lymph nodes. Its lower or deeper portion is of great surgical importance, since it forms a communicating region between the root of the neck and the axillary and mediastinal areas. The supraclavicular region is exposed in operations upon the inferior group of deep cervical lymph nodes, in procedures directed toward lesions of the subclavian vessels or of the brachial plexus, and in the removal of cervical ribs, which lie in intimate contact with the pleural dome. The nerve trunks are grouped about the lateral angle of the posterior triangle, while the vessels are deep and mesial (Fig. 199).

The inferior portion of the region is covered by the platysma. Of the vessels piercing the platysma, only the external jugular vein is of surgical importance. It runs vertically over the sternocleidomastoid muscle to empty into the subclavian vein in the mesial angle of the base of the fossa (Fig. 156). The posterior belly of the omohyoid muscle swings across the fossa to the scapula, dividing it into a larger, superior and lateral *omotrapezius area*, and a smaller, inferior and medial *omoclavicular area*.

Anterior and Posterior Walls of the Fossa. The investing layer of the deep cervical fascia divides to enclose the trapezius and sternocleidomastoid muscles. The intervening layer of enveloping fascia or the *anterior wall* of the fossa is a fairly loose aponeurosis which passes over, and is adherent to, the clavicle and extends into the thoracic region as the pectoral fascia. The pretracheal fascia sheathes the posterior belly of the omohyoid muscle and covers the lower part of the region deep to the enveloping fascia (Fig. 157). The two fascial planes are separated by areolar tissue. The pretracheal layer can be traced downward behind the clavicle and the subclavius muscle, to both of which it adheres. It forms the outer fibrous investment for the subclavian vein. When the omohyoid muscle has close connections with the clavicle, the pretracheal fascia is limited in extent and the omoclavicular triangle is smaller.

The *posterior wall* or floor of the fossa is composed of groups of muscles which extend downward and outward from the cervical column. The scalenus medius and posterior muscles, although fused in their upper portions, form most of the anterior portion of the floor of the triangle, and are attached to the first and second ribs. The subclavian artery and the trunks of the brachial plexus, as they emerge from the cleft between the anterior and middle scalene muscles, lie on the floor of the triangle (Fig. 200).

The anterior scalene muscle, normally completely covered by the sternocleidomastoid muscle, is exposed in operations within the supraclavicular region when the sternocleidomastoid is retracted mesially. The anterior scalene muscle arises from the transverse processes of the third, fourth, fifth and sixth cervi-

* Woodhall: Arch. Surg., 74: 122-7, 1957.

cal vertebrae, and runs downward and laterally to insert on the scalene tubercle and ridge, and on the medial margin of the first rib. All the muscles of the floor of the supraclavicular fossa are covered by prevertebral fascia. The subclavian vein lies between the anterior scalene muscle and the clavicle, and grooves the upper portion of the first rib. Behind this muscle lie the subclavian artery and the large nerve trunks of the brachial plexus.

VESSELS OF THE SUPRACLAVICULAR FOSSA. The important structures within the supraclavicular fossa are the vessels and nerves which cross the root of the neck, traverse the axilla, and supply the upper extremity. The lymph nodes of the fossa establish communication between the axilla and the superficial and deep cervical glands.

The *right subclavian artery* is typically a subdivision of the innominate (Fig. 214, *a*), while the *left subclavian artery* arises directly from the arch of the aorta. The artery of the right side begins at a point deep to the sternoclavicular joint; the artery of the left side, the longer of the two, arises within the thorax on the left side of the trachea. Both arteries run lateralward in an arching course across the root of the neck, grooving the pleural cupola. The height attained by the summit of the arch varies, the average being approximately 1 cm. above the

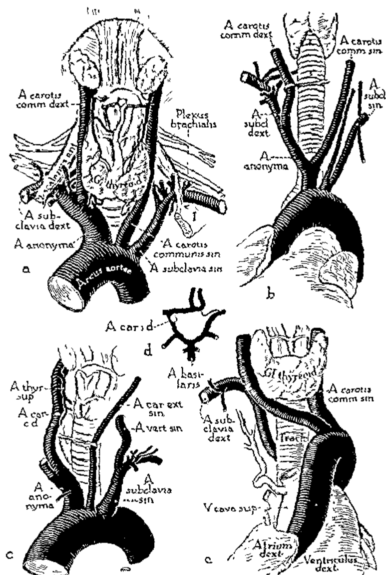


Fig. 214. BRANCHES OF THE AORTIC ARCH. VARIATION IN THE PATTERN OF ORIGIN.
a, Regular schema; *b*, left common carotid from the innominate; *c*, absence of left carotid artery; *d*, form of the arterial circle (of Willis) in the same specimen; *e*, retro-esophageal right subclavian artery.

sternal extremity of the clavicle. In persons with slender neck and sloping shoulders the arch is likely to be high; contrariwise, in short-necked persons the vessel may not appear above the clavicle (other variation, Fig. 214).

In the neck, on the way to the axilla, each artery lies between the sternocleidomastoid, externally, and the scalene muscles, internally. Each artery is conveniently divided into three portions in reference to its *relation—medial, posterior or lateral*—to the anterior scalene muscle. As the subclavian artery approaches the axilla, behind the clavicle, it occupies the scalene fissure in the subclavian sulcus of the first rib. When a cervical rib is present, it is overlaid by the artery; as a consequence, the *expansile pulsations may be mistaken for a* subclavian aneurysm.

Unlike the neighboring vessel, the common carotid, the subclavian artery gives off branches in considerable number in widespread distribution. From the subclavian, either directly or through intermediary trunks, branches are sent outward as follows: upward and backward to the superficial and deep musculature of the neck; upward into the cranial cavity, to take part in vascularization of the brain; medialward to the thyroid gland; downward to the trachea, bronchi, esophagus, pectoral and thoracic musculature and mammary gland; and lateralward to the muscles of the shoulder and back. Continuing as the axillary, and in turn as the brachial, the main artery becomes the source of supply to the arm, forearm and hand.

Dorsally and laterally, the trunks of the brachial plexus are in relation to the subclavian artery, and accompany it to the apex of the axilla. Anteriorly, the artery is covered by the subclavian vein, which occupies the space between the anterior scalene muscle and the clavicle. Relations between the clavicle and artery vary considerably. When the shoulder is elevated, the clavicle encroaches on the supraclavicular fossa and hides the artery in the deep recess formed behind the bone. When the shoulder is depressed, the fossa is largest and the artery is most superficial, so that pulsations sometimes are detected in the mesial angle.

Although well protected in the medial portion of its course by *the overlying sternocleidomastoid* muscle and the inner end of the clavicle, the subclavian artery is liable to injury by penetrating wounds in the lower neck region. *The trunks* of the brachial plexus, because of their proximity to the vessel, may be injured at the same time. The relationship of the pleura *with the first and second portions of the artery* must be borne in mind in ligating the artery. Circulation of the vessel may be controlled by firm pressure against the first rib. Tumors located deep in the supraclavicular fossa so overlie the pleura that it may be torn easily in removing them.

The two branches of the subclavian artery in the supraclavicular fossa are the transverse scapular and transverse cervical, which, with the inferior thyroid artery, form the thyreocervical trunk (Fig. 195, *d*).

The *subclavian vein* is the direct continuation of the axillary or main vein of the upper extremity, *and is so named at the lateral margin* of the first rib. Through its tributary, the external jugular, it collects blood from the head and neck. It runs mesially, a little below and in front of the corresponding artery, separated from it by the lower part of the anterior scalene muscle. More laterally, it is in relation with the subclavius muscle, which is applied to the inferior surface of the clavicle (Fig. 200).

The *supra-omohyoid* and *infra-omohyoid groups* of *lymph nodes* are continuous with the upper deep cervical glands of the sternomastoid region. These nodes drain the posterior scalp and the nuchal, pectoral, deltoid and axillary regions. The relations of the nodes to the thoracic and right lymphatic ducts explain the gland involvement in visceral disease. The easily invaded cellular tissue is in broad com*munication with the parotid, sternomastoid* and axillary regions, and with the mediastinum. The *right lymphatic duct*, not always present as a single trunk, drains the lymph from the right half of the supradiaphragmatic area of the body. The *thoracic duct* collects the lymph from the entire subdiaphragmatic portion of the body, as well as from the left half of the supradiaphragmatic area. From the mediastinum it runs forward and outward in an arched course to terminate in the confluence of the subclavian and left internal jugular veins (Fig. 204). The arch of the duct lies above and crosses the subclavian artery. Injury to the duct in supraclavicular lymph node dissection is *accompanied by abundant lymphorrhea.*

BRACHIAL PLEXUS. The individual nerves which make up the brachial plexus are the ANTERIOR ROOTS OR PRIMARY DIVISIONS of the fifth, sixth, seventh and eighth cervical and

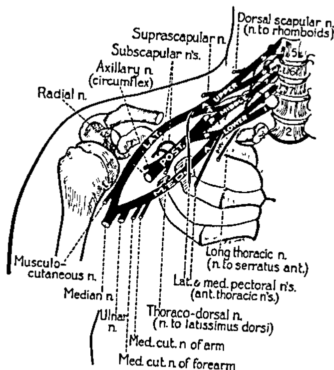


Fig. 215. BRACHIAL PLEXUS; SCHEMATIZED IN HAVING THE COMPONENTS SEPARATED AND DRAWN OUT OF SCALE.

Showing, diagrammatically, the way in which, by plexiform interchange, the peripheral nerves are derived from various cervical components (that is, levels of the spinal cord). Undivided anterior rami are indicated by 5, 6, 7 and 8 (cervical) and 1 (thoracic); trunks are upper, middle and lower; divisions are indicated by *A's* (anterior) and *P's* (posterior); the cords are lateral, posterior and medial, so designated on the basis of their relation to the brachial artery (which is not included in the figure). Cord derivation of named nerves differs: the musculocutaneous nerve arises from the lateral cord, the ulnar nerve from the medial cord, the median nerve from both cords. (From Haymaker and Woodhall: Peripheral Nerve Injuries.)

first thoracic spinal nerves, with occasional twigs from the fourth cervical and second thoracic nerves (Fig. 215). These roots emerge through the slitlike interval between the anterior and middle scalene muscles, and appear in the lower part of the posterior triangle of the neck (Figs. 199, 200).

On the middle scalene muscle the anterior primary divisions unite to form TRUNKS. Those of the fifth and sixth cervical nerves form the *upper trunk;* that of the seventh continues laterally alone as the *middle trunk;* and those of the eighth cervical and first thoracic nerves form the *lower trunk.* Each of the trunks continues undivided to a point just beyond the lateral margin of the anterior scalene muscle.

As these branches pass downward and laterally behind the clavicle, they are assembled in compact bundles or CORDS, which are named with reference to their location about the axillary artery. The anterior divisions of the upper and middle trunks constitute the *lateral cord;* those of the lower trunk form the *medial cord.* The posterior divisions of the three trunks constitute the *posterior cord.* Before the cords divide to be distributed to the upper extremity, they form several important nerves. From the lateral cord, the lateral anterior thoracic nerve is given off to the pectorals; from the posterior cord are given off the subscapular nerves; and from the medial cord, the medial antibrachial, medial brachial cutaneous and medial anterior thoracic (pectoral) nerves.

The cords then supply TERMINALS to the extremity. The lateral cord divides into the *musculocutaneous* and the lateral head of the *median* nerve. The medial cord, after forming the medial head of the median nerve, continues as the *ulnar* nerve. The posterior cord, after giving off the subscapularis and axillary nerves, continues as the *radial* (musculospiral) nerve (Fig. 215).

As would be expected from the inclusiveness of its origin, proximally, from at least five segments of the spinal cord, and from the intricate manner in which anastomotic connections are formed to give rise, distally, to nerves of extensive cutaneous and motor supply, variations in

pattern of the brachial plexus are numerous and in some instances striking. The succession of separations and conjunctions which groups of nerve fibers undergo, in passing from their points of medullary origin to those of ultimate incorporation into named nerves, accounts for the variation observed in length of the rami, trunks, divisions and cords. For example, the length of the upper trunk varied (in 72 per cent of 102 extremities) between 4 and 5.5 cm., and that of the lower trunk between 1 and 3 cm.

Trauma in the supraclavicular region may contuse, compress or lacerate different portions of the plexus. The subclavian artery and vein, located distally and close to the clavicle, usually escape. Injuries in the region of the scaleni involve the roots of the plexus. Trauma within the confines of the supraclavicular fossa involves the trunks; injuries behind the clavicle and in the upper axilla involve the cords. Compression of the trunks and cords may be caused by tumors or aneurysm formation; they may be injured by a fractured clavicle.

Skeletal Structures. The skeletal structures in the region are the clavicle and the first rib. The clavicle and scapula form the shoulder girdle, which suspends the upper extremity and maintains it at a uniform functioning distance from the trunk. The *clavicle* has two curves: a medial with a convexity forward, and a lateral with a concavity forward (Fig. 216). The longer medial curve presents important relations inferiorly and posteriorly with the subclavian vessels and with the cords and terminal nerves of the brachial plexus, being separated from them only by the subclavius muscle and its embracing sheath from the axilla. The lateral curve overlies the coracoid process, with which it is connected through the coracoclavicular ligaments.

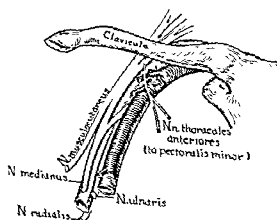


Fig. 216. VASCULAR RELATIONS OF THE BRACHIAL PLEXUS BEHIND THE CLAVICLE AND IN THE AXILLA. (After Tinel.)

The sternal extremity of the clavicle has posterior relations with the innominate vein. On the right side it is related to the bifurcation of the innominate artery; on the left, to the common carotid artery. On both sides the sternohyoid and sternothyroid muscles separate the bone from these vessels. The sternal head of the sternocleidomastoid muscle overlies the clavicle in front. The shaft of the bone is superficial throughout.

The *body of the first rib* is placed so that its superior surface is almost flat. In its middle portion it presents two transverse grooves: a posterior groove, through which courses the subclavian artery, and one just anterior to it, through which runs the corresponding vein. Between the two is the scalene tubercle for the attachment of the anterior scalene muscle.

Surgical Considerations

Cervical Rib and the Scalenus Anticus Syndrome. The congenital anomaly of supernumerary ribs usually occurs in the cervical region, although occasionally in the lumbar. It seldom is discovered unless it causes symptoms or unless attention is directed to the region in study or observation of other conditions. While supernumerary ribs are small and of little practical importance in the lumbar region, those in the cervical region may be of considerable importance.

A cervical rib attached to the transverse process and body of the seventh cervical vertebra (Fig. 217) may vary in size from a simple exostosis to a fully formed rib, and may be either unilateral or bilateral. When small, it may present a free ventral extremity or may be joined to the first thoracic rib by a fibrous attachment. When the rib is more than 5 cm. long, it displaces the subclavian artery and the brachial plexus upward. The anterior extremity of the rib, in a rare instance, may reach the sternum, but usually articulates or fuses with the first (thoracic) rib. Since the chest is lengthened by one rib, there is a higher arch and a sharper curve in the subclavian artery. With the arch of the subclavian artery well up into the soft parts of the neck and above the clavicle, it runs greater risk of injury from



Fig. 217. CERVICAL RIB ON THE LEFT SIDE.
(From Andrews.)

trauma. The pulsation of an abnormally high subclavian artery may suggest the diagnosis of aneurysm; aneurysm of the axillary artery has been observed in patients with cervical ribs.

Unless the rib is well developed, it is too short to support the artery, and may be crossed only by the lower trunk of the brachial plexus. The most frequent results of the anomaly are the nerve phenomena referable to the hand and arm, a consequence of pressure on roots of the brachial plexus. It should be definitely borne in mind that about half of the patients with a cervical rib have no complaints referable to it. Neuritic symptoms of involvement of the lower trunk (C 8 and T 1) manifest themselves as pains running down the ulnar side of the arm and forearm, the areas supplied by the roots involved. Progressive paresis and wasting occur in the intrinsic hand muscles, and trophic changes in the arm accompany the atrophy and loss of power which correspond to the areas of anesthesia. Upward pressure on the artery may cause compression to the degree that pulsation at the wrist is absent, and the limb becomes anemic. If the collateral circulation proves inadequate, gangrene may occur in the fingers.

When the same symptoms are present and cervical ribs cannot be demonstrated, the term *scalenus anticus syndrome* is used and has been established as an indefinite entity. In fact, the effect of the scalenus anticus muscle is considered the chief factor responsible for the symptoms, whether a cervical rib is present or not, and its action without or with the latter is diagrammed in Figure 218. The anterior scalene muscle compresses the subclavian artery and the brachial plexus against the first rib, or against the fibrous prolongation of a cervical rib when the rib itself causes no trouble. This muscle may produce an abnormal lift to the first rib and thereby cause upward compression of the subclavian artery and the brachial plexus. Excessive muscular development of the scalenus anticus in a young adult, or the sagging of the shoulder girdle in an older person, may cause this syndrome. High fixation of the sternum and ribs, low origin of the brachial plexus, or elevation of the first thoracic rib from spasm of the anterior scalene muscle may produce the same symptom complex.

Cervical ribs causing pressure require removal. The whole area may be exposed widely by a curvilinear incision passing vertically down the posterior margin of the sternocleidomastoid muscle and extending laterally along the clavicle. The brachial plexus and subclavian artery are displaced forward, and the middle scalene muscle is separated from the under surface of the rib, care being taken to avoid injury to the pleura. The rib is divided as close as possible to its vertebral extremity. In the presence of a cervical rib without tendinous attachments, and without obvious pressure from behind, the condition may be alleviated by separating the tendon of the anterior scalene muscle from its attachment to the first rib or to the cervical rib or its anterior fibrous

Ant. scalenus m

Brachial plexus (Released)

B

Subclavian artery (Constricted)

Brachial plexus (Constricted)

A

Scalenus Anticus Syndrome

A. Compression of subclavian artery and brachial plexus before muscle section.

B. Relief of pressure on artery and brachial plexus by section of scalenus anticus muscle

D.

Cervical rib with scalenus anticus syndrome

C. Muscle and not rib causes compression.

D. Scalenus anticus section relieves compression

Rongeur

F

Cervical rib and scalenus anticus syndrome

E. Fibrous attachment of rib and anterior scalenus muscle both cause constriction

Cervical rib and scalenus anticus syndrome.

F. Compression relieved by removal of rib and section of muscle

E

Fig. 218. CERVICAL RIB AND THE SCALENUS ANTICUS (ANTERIOR) MUSCLE.
(Modified from Adson and Coffey.)



Fig. 219. VASCULAR TEST FOR SCALENUS ANTICUS (ANTERIOR) SYNDROME.

a, The subclavian and radial arteries identified, *b*, Positive response: pulsations of arteries obliterated by inspiration, elevation of the patient's chest and rotation of the head to the affected side. (From Adson: Surg., Gynec. & Obst., 85: 687-99, 1947.)

termination. In this way the subclavian artery and whatever nerve elements of the brachial plexus are caught between the tendon and bony parts are able to free themselves by sliding downward and forward (Adson, Coffey).

In the selection of patients for operative treatment, Adson repeatedly emphasizes the importance of the vascular test (Fig. 219), believing that little is accomplished by the scalenotomy procedure for the scalenus anticus syndrome without the presence of cervical ribs or unusually large transverse cervical processes unless the vascular test is positive. Even without symptoms, if the test obliterates the radial pulse, he considers that scalenotomy should be performed to prevent the danger of atheromatous thickening of the subclavian artery under the scalenus muscle.

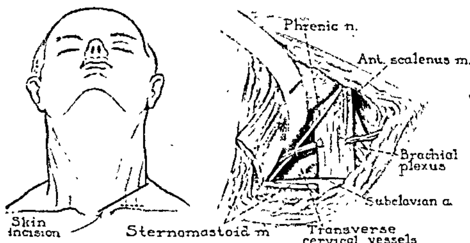


Fig. 220. ANTERIOR APPROACH FOR CORRECTION OF SCALENUS ANTICUS SYNDROME.

Incision should follow the lines of the skin. After reaching the deeper tissues it is important to carry the dissection upward on the anterior scalene muscle for 5 cm. in order thoroughly to expose and protect the phrenic nerve. On the medial side of the scalene the pleura may be seen. Adhesions in the area may require careful dissection of the anterior scalene tendon from the subclavian artery, and the latter from the brachial plexus. After division of the tendon of the anterior scalene from the first rib, the muscle fibers retract upward, relieving compression and allowing the subclavian artery to take on its normal caliber and retract downward. Additional steps occasionally needed to relieve compression are (1) excision of 3 to 5 cm. of a particularly hypertrophic anterior scalene muscle and (2) subtotal resection of a completely formed and high cervical rib. (From Adson: Surg., Gynec. & Obst., 85: 687–99, 1947.)

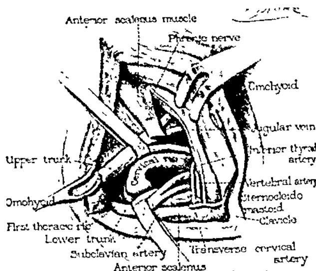


Fig. 221. CORRECTION OF SCALENUS ANTICUS SYNDROME (CONTINUED).

Separation of upper and lower trunks of the brachial plexus through incision shown in Figure 220 permits exposure of cervical rib if its resection is advisable. (From Adson. Surg., Gynec. & Obst., 85: 687–99, 1947.)

Figures 220 and 221 show an excellent approach for correction of the scalenus anticus syndrome.

LESIONS OF THE BRACHIAL PLEXUS IN GENERAL. The brachial plexus or any of its parts may be injured directly in penetrating wounds, by compression from a bony callus, foreign body, scarred fibrous mass, or simple hematoma in the supraclavicular or axillary fossa. The plexus may be injured extensively by upward or downward traction on the extremity or downward pressure on the shoulder, with or without dislocation. Injury may involve the roots, trunks, cords or their branches, resulting in a great variety of clinical pictures. The cervi*cal nerves divide almost immediately after their* formation into anterior and posterior primary divisions. The posterior primary or dorsal division supplies not only the dorsal axial musculature, but also the skin over the region of the back. Therefore a lesion just outside the spinal canal shows, in addition to other signs of injury, an area of anesthesia to all forms of sensation over the region of the back supplied by the primary dorsal division affected. In an injury lateral to the primary division of the spinal nerve the dorsal division escapes, and anesthesia is not produced.

ERB-DUCHENNE OR UPPER ARM TYPE OF PARALYSIS. Paralysis from injury to the upper trunk of the brachial plexus is known as Erb-Duchenne or upper arm palsy. The fifth and, to a less extent, the sixth cervical nerves are involved. The injury commonly results from downward traction of the shoulder in complicated delivery. The pull tears the upper trunk proximal to the origin of the suprascapular nerve, but distal to the origins of the long thoracic nerve (of Bell) and dorsal scapular nerve (to the rhomboids). The deltoid, supraspinatus, infraspinatus and teres minor, innervated by the suprascapular and axillary nerves, are paralyzed, and the arm is rotated mesially by the latissimus dorsi (C 6, 7, 8) and the sternal head of the pectoralis major, the latter because of its supply from the anterior primary branches of C 8 and T 1. The biceps and brachioradialis muscles are paralyzed, and *the forearm is pronated by the pronator quadratus* (C 7, 8; T 1), the pronator teres being supplied by C 6. Since the arm is fully pronated, the extensor digitorum communis and extensor carpi ulnaris muscles (C 6, 7, 8) may be able to produce slight flexion at the elbow.

When the lesion is confined to the anterior primary division of C 5, no sensory changes can be noted, since this nerve is not responsible for the exclusive supply of any definite area of skin. If C 6 also is involved, there usually is some loss of sensation on the outer aspect of the arm and forearm.

In the treatment of such *conditions the* paralyzed muscles must be relaxed, lest they become overstretched by the unopposed action of the unparalyzed antagonistic muscles. To accomplish relaxation and correct deformity,

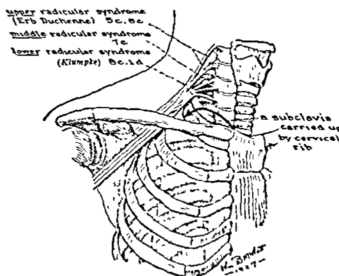


Fig. 222. TYPES OF BRACHIAL PALSY.

Upper radicular or Erb-Duchenne syndrome, middle radicular syndrome, and lower radicular or Klumpke syndrome. Effects of a cervical rib are shown. (Babcock.)

three postures of the arm must be maintained: abduction, lateral rotation, and flexion.

Klumpke or Lower Arm Type of Paralysis. Klumpke or lower arm paralysis is the result of upward traction on the shoulder (Fig. 222). It may be sustained in falling from a high place and seizing something to break the fall, or may occur in a breech presentation when the arms are carried over the head. The first thoracic spinal nerve is the one usually involved, but the whole lower trunk (C 8, T 1) may be torn across. Since the intrinsic muscles of the hand supplied by the ulnar nerve are paralyzed, a clawhand develops. In a clawhand the fingers are hyperextended at the metacarpophalangeal joints and are flexed at the interphalangeal joints. Should all the lower trunk be affected, the flexor and extensor muscles of the fingers also are paralyzed. There is diminution of sensation over the mesial side of the arm, forearm and hand.

Injuries to Cords of the Plexus. The *medial cord* may be stretched or torn in subcoracoid dislocation of the head of the humerus or in rough methods of reduction of the dislocation. After such an injury, sensory changes are found in the domain of the cutaneous nerves of ulnar and median derivation. The muscles supplied by the medial cord are paralyzed. They are the intrinsic muscles of the hand supplied by the ulnar nerve and the medial head of the median nerve, the flexor carpi ulnaris muscle, and the part of the flexor digitorum profundus muscle supplied by the ulnar nerve.

When the *lateral cord* is injured, the muscles supplied by the musculocutaneous nerve, the *biceps, coracobrachialis and brachialis (anticus)*, are partially paralyzed. There is paralysis of the superficial and deep muscles of the anterior forearm, supplied by the lateral head of the median nerve. There is partial loss of epicritic sensation in the areas supplied by the musculocutaneous and median nerves.

CHAPTER 9

Thoracocervical Region, "Root of the Neck"

DEFINITION AND BOUNDARIES. The thoracocervical region, or the root of the neck, forms a boundary between the neck and the thorax. The area adjoins the thoracic inlet and is occupied mainly by structures which enter and emerge from the thoracic cavity. It affords an approach in the operative treatment of innominate and subclavian aneurysms. To be considered here are the inner extremity of the clavicle, the manubrium of the sternum, the sternoclavicular joint, and the subclavian vessels in their first and second portions.

SUPRASTERNAL FOSSA. A duplication of the enveloping fascia of the neck forms a triangular cavity above the manubrium (p. 168).

INNOMINATE AND SUBCLAVIAN VEINS. When the sternothyroid and sternohyoid muscles, with their investing pretracheal fascia and the overlying enveloping fascia, are divided at their sternal attachments and reflected upward, the large vascular trunks at the root of the neck are exposed. The terminal portions of the subclavian and internal jugular veins and their junction conceal most of the deeper structures. The innominate veins join opposite the first costal cartilage on the right to form the superior vena cava. To reach this point, the left vein passes behind the manubrium of the sternum; it is three times as long as the right vein.

The innominate veins, through their large jugular and subclavian tributaries, receive blood from several regions over a widespread area (Fig. 185). From the head come veins which return blood from the brain and cranial meninges, the cephalic musculature and related tissues, the orbital contents, the nose, mouth and salivary glands; in the neck, veins which are direct or indirect tributaries of the innominates come from the cervical musculature, the spinal cord and its meningeal coverings, the pharynx and larynx, the trachea, and the thyroid gland and thymus; through the subclavian vein, blood is received from the entire upper extremity, the thorax and the back.

The *right innominate vein* lies deep to the inner end of the right clavicle, from which it is separated by the attachments of the sternohyoid and sternothyroid muscles. It is in relation with the mesial surface of the right pleura and partly overlies the innominate artery. It runs downward almost vertically into the superior vena cava.

The *left innominate vein* passes from left to right and a little downward behind the upper part of the manubrium to the lower margin of the first right cartilage, where it terminates in the superior vena cava. It is covered in front by the left sternoclavicular joint, and on the right is overlapped slightly by the right pleura. The remains of the thymus lie between it and the sternum. It is on a level with, or slightly above, the upper margin of the manubrium. It may be endangered during a low thyroidectomy, a low tracheotomy, or in the removal of a tumor in the root of the neck.

The *subclavian vein* on each side is a direct continuation of the axillary vein. At the junction of the clavicle and sternum the subclavian unites with the internal jugular vein to form the innominate. Through its tributary, the external jugular vein, it receives blood from the head and neck. The subclavian vein begins at the outer border of the first rib and runs mesially, almost transversely, behind the clavicle. It lies in front of the subclavian artery, which it accompanies in its course, save where separated from the artery by the anterior scalene muscle. A penetrating wound may injure both vessels at any point along their course and cause the formation of an arteriovenous fistula. The vein in its outer course has an

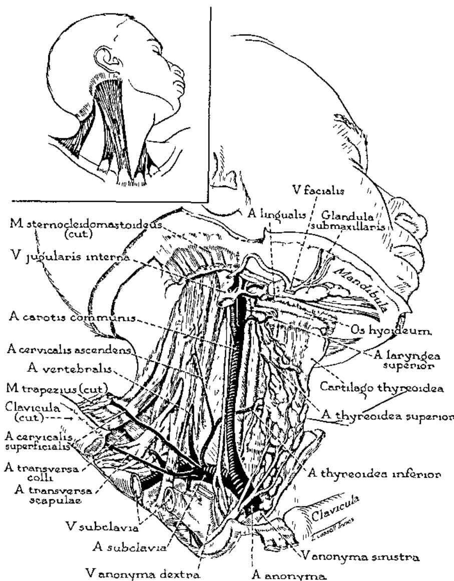


Fig. 223. DEEP ANATOMY OF THE NECK, IN ANTEROLATERAL VIEW.

The sternocleidomastoid muscle (see inset) and the clavicle have been removed, together with the infrahyoid muscles. The internal jugular vein has been excised; a segment has been removed from the right subclavian vein in order to expose laterally the subclavian artery in its relation to the scalene muscles and the brachial plexus. Medially, the thyroid gland and its blood vessels are revealed.

anterior relation with the subclavian muscle, its anterior wall being united to the fascia which clothes that muscle.

Since the subclavian vein occupies the acute angle between the clavicle and the first rib and has slight resistance, it suffers compression from any outgrowth from these bones. In fracture, the interposed subclavian muscle protects the subclavian vein and artery and the brachial plexus. The *connection of the vein* with the fascia of the subclavian muscle and with the pretracheal fascia increases or maintains its caliber during inspiration. Elevation of the arm has a similar action, which fact *should be remembered in the event of injury* to the vein during operation, since elevation of the clavicle widens the rent. The internal jugular and subclavian veins unite in an acute angle which opens laterally. In the apex of the angle on the right, the external jugular vein and right lymphatic duct open into the subclavian vein. In the apex on the left, the external jugular vein and thoracic duct (p. 215) open into *the subclavian vein.*

First and Second Portions of the Subclavian Artery. On the right side the subclavian artery arises from the innominate artery posterior to the sternoclavicular joint; on the

left it arises from the aortic arch posterior to the upper half of the manubrium. It occupies not only the root of the neck, but also the superior mediastinum (Figs. 223, 224). As the subclavian artery turns laterally (*first portion*), it lies behind the beginning of the left innominate vein. The thoracic duct arches over it, and behind it lie the apex of the pleural sac and the lung. Ligation of the first portion is much more difficult on the left than on the right.

The *second* or *retroscalene portion* of the artery is located in the triangular space between the anterior and middle scalene muscles, the base or floor of the area corresponding to the first rib. Above and lateral to it are the trunks of the brachial plexus. To uncover the artery in this position, the anterior scalene muscle must be sectioned. Because of the presence of the phrenic nerve on its medial border, the section of the anterior scalene muscle cannot be complete; it can involve only the outer portion.

Aneurysm of the subclavian artery, as a rule, involves the *third* or *extrascalene portion*, and appears as a swelling in the posterior triangle of the neck just above the clavicle. As it increases in size, it may fill the entire supraclavicular space and cause pressure phenomena of the brachial nerves, with motor and sensory disturbances over their respective areas of distribution. Edema of the upper extremity may occur as a consequence of pressure of the aneurysm against the subclavian vein, interfering with the venous return. The deep location and relations of the first portion of the subclavian artery and its numerous, closely grouped, large branches are sufficient to show that its ligation for subclavian aneurysm must be attended by considerable difficulty and some danger.

The large and important *vertebral artery* is the first branch from the subclavian and arises from the upper and posterior part of the first portion (Fig. 191). The *thyreo-cervical trunk* is the next large division arising from the first portion of the subclavian artery. The *internal mammary* is given off from the lower border of the first portion of the subclavian artery, inclines downward, forward and inward behind the clavicle, and enters the thorax behind the first costal cartilage (Fig. 224). The *costocervical trunk* (superior intercostal artery) branches from the posterior aspect of the second portion of the subclavian artery on the right, and from the first part on the left. It courses upward and backward over the dome of the pleura to the neck of the first rib. This artery, which supplies the first and occasionally the second intercostal space, brings into the subclavian and axillary circulation an anastomosis with the whole intercostal (descending aorta) circulation.

For simple ligation of the subclavian artery,

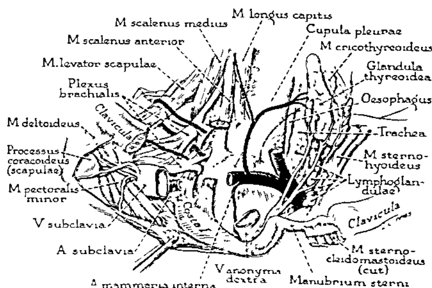


Fig. 224. DEEP CERVICAL ANATOMY; DISSECTION CONTINUED.

An additional segment of the vein has been excised to include a portion of the innominate. Similarly, a piece has been cut from the subclavian artery. In this way the cupula of the pleura is exposed, as it rises to an appreciable extent above the level of the first rib.

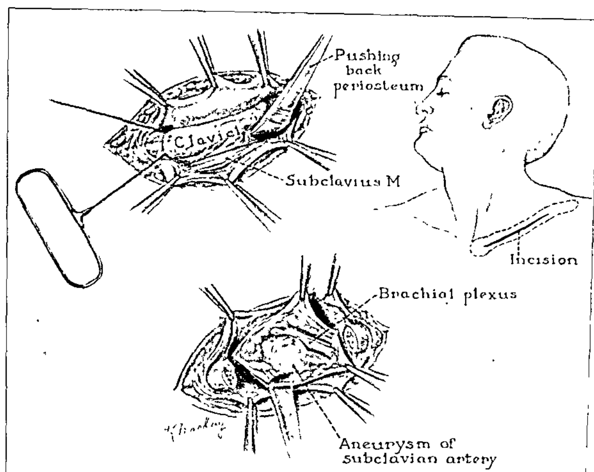


Fig. 225. INCISION USING RESECTION OF THE CLAVICLE FOR BETTER EXPOSURE OF THE SUBCLAVIAN ARTERY AND OTHER GREAT VESSELS AND THEIR BRANCHES AT THE BASE OF THE NECK.

The brachial plexus can also be developed. The medial end of the incision may be extended up the neck to deal with carotid jugular aneurysms; the lateral end can be extended and swung downward for axillary lesions. The part of the clavicle removed depends upon the region to be exposed, and the excised segment is not replaced. There is little postoperative discomfort or deformity, the area becomes firm, and the shoulder girdle is adequately fixed within 2 weeks. New bone can be palpated a few weeks later. (From Elkins and Cooper, Jr.: J. Bone & Joint Surg., 44: 117-19, 1946.)

the anterior approaches for the cervicodorsal sympathetics or scalenus anticus syndrome can be used (Figs. 220, 221). However, to better expose this area for operations on aneurysms or arteriovenous fistula of the subclavian, axillary, lower carotid and innominate vessels, or to view the brachial plexus, a resection of the clavicle (Fig. 225) is of great help. If the medial half of the clavicle is removed, the cartilage should also be excised. Excision of a portion of the adjacent sternum may give added exposure.

CHAPTER 10

Nuchal or Posterior Region of Neck

Definition and Boundaries. The nuchal region consists largely of retrospinal soft parts. It is bounded above by the superior nuchal line of the occipital bone, and anterolaterally by lines curving from the mastoid process to the tip of the acromion process, roughly outlining the anterior margins of the trapezius muscles. Inferiorly, it is bounded by a horizontal line running through the spinous process of the seventh cervical vertebra and the acromion process of each scapula.

Surface Anatomy. In the medial line, and a little below the external occipital protuberance, is the depression of the suboccipital (nuchal) fossa. The lower part of the region presents the broad aponeurosis of the trapezius muscles, through which the spinous processes of the fifth, sixth and seventh cervical vertebrae can be felt. The thickness of the overlying soft parts makes clinical and surgical exploration difficult.

Superficial Structures. The dense subcutaneous tissue is continuous with that of the scalp, and is bound down to the aponeurosis overlying the trapezius muscle, especially in the upper part of the region. The skin of the area contains many sebaceous glands and hair follicles, the former the seat of acne, and the latter the starting point of infection. The areolae, which the fibrous tissue circumscribes, contain large quantities of fat, in which large lipomas may develop. The superficial vessels derived from the occipital and transverse cervical arteries are of little consequence. The superficial cervical veins return blood to the internal jugular.

Musculature. The superficial muscle layer is represented by the upper portion of the trapezius (C 3, 4, and N. accessorius), which arises from the superior nuchal line, external occipital protuberance, ligamentum nuchae, the spines of the seventh cervical vertebra, all the thoracic vertebrae, and the supraspinous ligaments. From this broad origin the fibers converge to the outer third of the posterior surface of the clavicle, the medial border of the acromion, and the superior border of the spine of the scapula. The ligamentum nuchae consists of the extensively developed cervical supraspinous ligaments, which extend from spinous process to spinous process, and is attached at their tips. The ligament forms an elastic partition between the muscle of the two sides of the neck. It is a morphologic equivalent of a similar ligament which maintains the head upward in quadrupeds. It atrophies in consequence of erect posture.

The second muscle layer is formed above by the splenius capitis and levator scapulae, and below by the major and minor rhomboids (Figs. 226, 227). In the third or deep layer are the long back muscles, the longissimus and iliocostalis. Immediately below the superior nuchal line is the fourth muscle layer, which consists of the four muscles uniting the occiput to the upper cervical vertebrae. These are the rectus capitis posterior major and minor and the obliquus capitis superior and inferior.

Skeletal Layer. The cervical column includes the atlas, epistropheus (axis) and five adjoining vertebrae (Fig. 228). It encloses the medulla and the cervical and most of the brachial divisions of the cord. The medulla occupies the interoccipito-atloid space. The cervical cord lies in the canal of the first three cervical vertebrae.

The atlas is the bony ring which, by its lateral masses, supports the cranium through the occipital condyles. Its ring form, absence of body, and its large articulating surfaces for the occipital bone permit flexion and extension, but no rotation. Rotation takes place at the atlanto-axial joints, which represent the articulations between the transverse processes

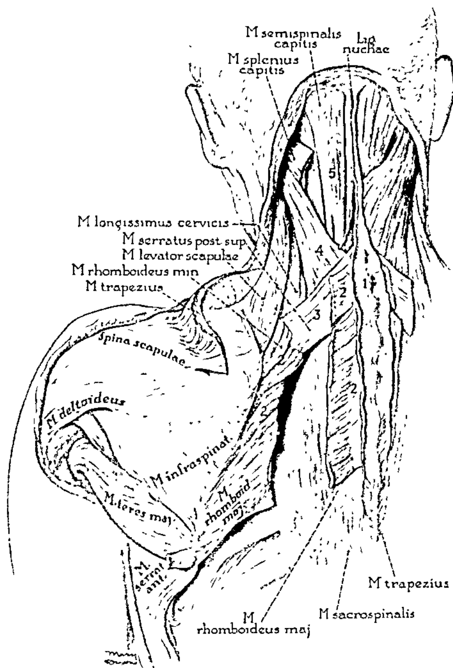


Fig. 226. MUSCLES OF THE BACK AND DORSUM OF THE NECK.

On the left a portion of the splenius capitis (at 4) has been removed, in order to expose the underlying semispinalis capitis (5); on the right side the corresponding muscle remains intact The following muscles have been cut near their vertebral origins: trapezius (1); rhomboideus major (2); serratus posterior superior (3), except for its upper segment.

of the axis and atlas and the atlanto-odontoid joint (Fig. 229). The odontoid process of the epistropheus is a cylindrical pivot, about which the epistropheus turns, carrying the head. The process is maintained firmly against the arch of the atlas by ligaments.

The upper cervical region is a frequent site for Pott's disease. The lesion in this location is particularly grave as compared with that in other vertebrae of the spine, since it may bring about a forward displacement of the head and atlas on the axis. This pathologic dislocation results in death if the odontoid pierces the medulla. The atlas and epistropheus, although the most mobile vertebrae in the spine, rarely are the seat of traumatic dislocation. Their freedom from dislocation is not altogether attributable to the strength of their attachments,

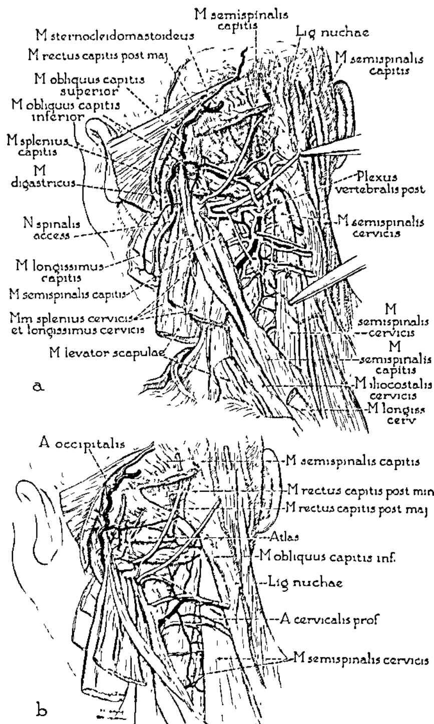


Fig. 227. BLOOD VESSELS AND NERVES OF THE DORSAL ASPECT OF THE NECK.

The trapezius, semispinalis, splenius and associated muscles have been cut and reflected in order to expose the suboccipital muscles, the occipital and deep cervical arteries, the posterior components of the external vertebral plexus of veins and the dorsal primary divisions (rami posteriores) of spinal nerves.

The greater occipital nerve (of the second cervical) seen as it passes through the trapezius near the latter's attachment to the occipital bone. The divisions of the third occipital nerve are held by forceps in *a;* the upper division is displaced from its *in situ* position medial to the greater occipital.

The occipital artery becomes superficial at the medial border of the sternocleidomastoideus, there to ascend in the subcutaneous tissue of the scalp. The deep cervical artery, ascending in the cleft between the capital and cervical divisions of the semispinalis, supplies these and adjacent muscles.

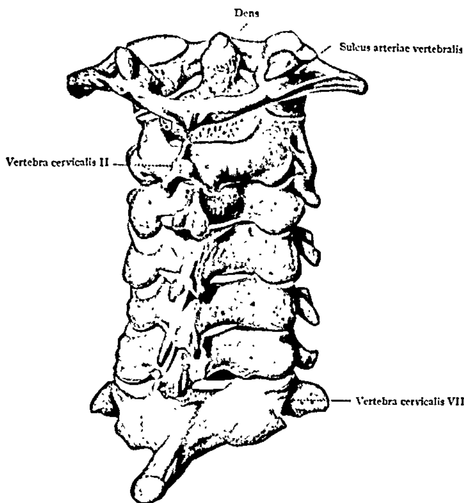


Fig. 228. POSTERIOR VIEW OF THE CERVICAL VERTEBRAE.
(Sobotta.)

but depends partly upon the flexion and extension possible in the lower cervical vertebrae.

VESSELS AND NERVES. The multiple muscle layers are supplied by the occipital, transverse cervical (ascending branch), profunda cervicis and vertebral arteries. The occipital artery (Fig. 227) is a branch from the external carotid. It enters the region at the posterior margin of the mastoid process, between it and the transverse process of the atlas. The artery lies under the insertions of the sternocleidomastoid and splenius muscles, and can be ligated in the sternomastoid region through the incision which leads to the external carotid artery (p. 212). The transverse cervical artery is a branch of the thyrocervical trunk which runs across the supraclavicular triangle (p. 225) to engage under the trapezius. It divides into ascending and descending branches, the ascending supplying the splenius capitis and levator scapulae muscles. The vertebral artery leaves the foramen in the transverse process of the atlas and curves backward and mesially to the posterior occipito-atloid ligament (Fig. 196). It perforates this ligament and enters the skull at the lateral surface of the medulla, contributing to the formation of the basilar trunk (Fig. 225).

The lymph vessels drain chiefly to the axillary lymph nodes, although a few pass to the occipital nodes.

The nerves of this region are the posterior primary branches of the cervical spinal nerves (Fig. 227). The first cervical (suboccipital) nerve passes backward between the occipital bone and the posterior arch of the atlas to supply the small and deep muscles about the occipito-axoid region. The posterior primary branch of the second cervical is the greater occipital nerve, which runs between the epistropheus and atlas to supply the bulging superficial musculature. The third cervical (small occipital) nerve is not as large as the

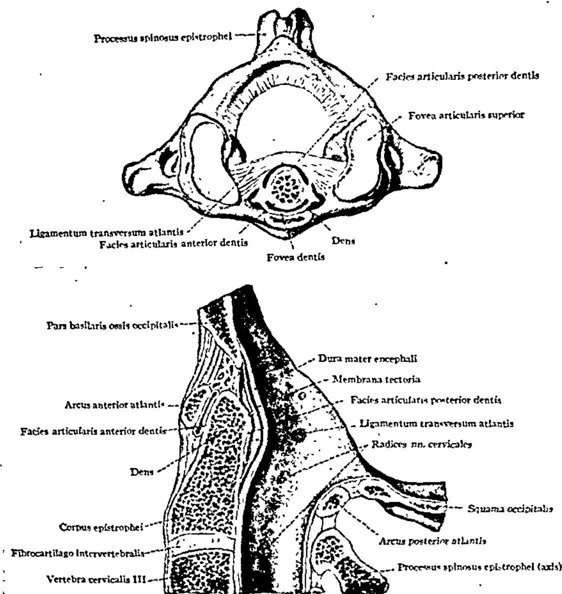


Fig. 229. ARTICULATIONS IN CERVICAL PORTION OF THE VERTEBRAL COLUMN.

Above, Atlanto-occipital joint, seen from above. The odontoid process (dens) of the epistropheus (axis) and the anterior arch of the atlas have been cut away. *Below*, Atlanto-axial (epistrophial) joint, seen in median sagittal section. (From Sobotta: Atlas of Human Anatomy.)

major occipital nerve, and the remainder of the posterior branches are progressively smaller.

Surgical Considerations

CARBUNCLE OF THE NECK. The nuchal region owes much of its surgical importance to the frequent occurrence of carbuncles. The initial infection starts in a single hair follicle or sebaceous gland, or in a group of them. It then invades the underlying fat columns in the subcutaneous layer and works its way slowly downward to the deep tissues. It does not spread laterally out of the columns until the infection is deep-seated. When a diffuse abscess is formed, the infection seeks an exit through the path of least resistance, the surrounding fatty columns which form multiple channels between the skin and the suppuration. The area involved frequently is extensive, covering the entire posterior region of the neck and spreading under the skin of the scalp and back. The central overlying skin becomes gangrenous, melting with the subcutaneous tissues into a large pus-filled ulcer with undermined,

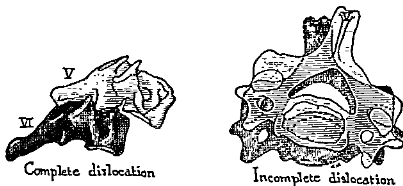


Fig. 230. COMPLETE AND INCOMPLETE DISLOCATIONS IN THE CERVICAL REGION.

slough-lined margins. A carbuncle in such a stage resembles a honeycomb, discharging bloody pus and large masses of skin and subcutaneous tissue. The entire mass of the induration may become gangrenous.

Treatment of large carbuncles consists in excision down to the deep fascia or muscle, followed by packing with moist antiseptic gauze. This procedure eliminates the long period of necrotic suppuration, reduces the toxic absorption, and gives prompt relief of pain. Hot antiseptic packs favor liquefaction, escape of slough, and rapid granulation.

POTT'S DISEASE (TUBERCULOSIS) OF THE CERVICAL SPINE. A classical sign of cervical spinal tuberculosis is the deformity caused by the collapse of vertebral bodies, which results in prominence of the spinous processes.

The upper or occipito-axoid section of the spine is peculiar in that it contains no body or *intervertebral disk, and that the extensive head* movements are carried out in special joints, handled by specialized sets of muscles. Disease here is more frequent in adults than in children and more dangerous than disease in other parts of the spine because of the neighboring vital centers, which risk injury by pressure or by displacement of the weakened vertebrae. The symptoms in typical cases are neuralgic pains referable to the terminations of the auricular and occipital nerves. The neck is stiff, with the head fixed or tilted to such a degree that it simulates torticollis. The affected vertebrae are sensitive to direct pressure.

The atlanto-axoid joint lies just behind the posterior wall of the pharynx on the same level as the upper teeth. Abscess may point into the pharynx early in the course of the disease. Pott's disease of the cervical spine is characterized by restriction of motion in the occipito-atloid joint. Any restriction in the movements of the head should be observed carefully.

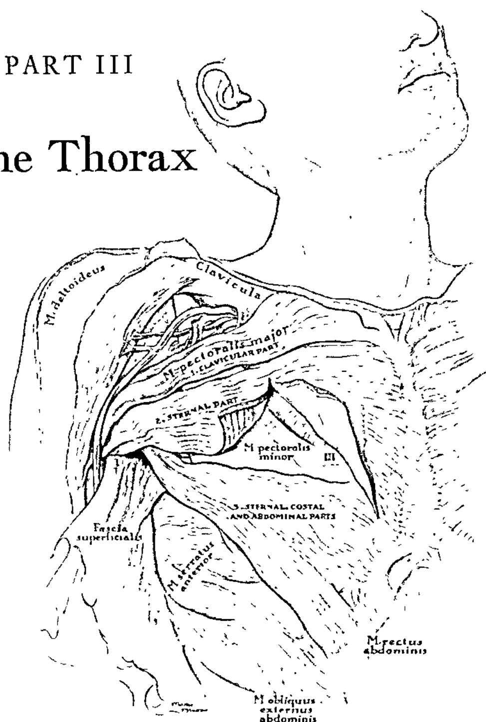
In disease of the lower vertebrae the spine becomes straighter and stiffer than in disease in the upper vertebrae. A slight backward thickening may indicate the location of the lesion. The head and chin are inclined to one side because of the contraction of the lateral muscles of the head and neck. In the contracture of torticollis, on the other hand, the chin is elevated and tilted away from the contracted sternocleidomastoid muscle.

FRACTURES AND DISLOCATIONS. Although the atlas and axis are the most mobile vertebrae in the cervical spine, they rarely are the seat of *traumatic dislocation*, because of the strength of their check ligaments.

Dislocation in the cervical column generally is forward, and occurs in the last three cervical vertebrae where the greatest movement in flexion and extension is permitted (Fig. 230); it is caused by forced flexion or extension. Dislocations and fractures are especially serious because of involvement of the phrenic and other nerves supplying the muscles of respiration. Fractures of the fourth or fifth cervical vertebra may involve the upper part of the brachial plexus. The consequences are paralysis and anesthesia of the upper extremities, as well as of the trunk and lower limbs.

PART III

The Thorax



PECTORAL AND RELATED MUSCULATURE

CHAPTER 11

Thorax in General

The bony thoracic cage is made up of the sternum, ribs and vertebrae, covered in front and on the sides by a thin layer of soft parts. It houses and protects the main organs of circulation and respiration, and the esophageal portion of the digestive apparatus. External violence may cause injury through the intercostal spaces, which are poorly protected areas, or may overcome the resistance of the shielding ribs, which then become offending factors, wounding the structures within the costal cage. The entire cage is accessible to well planned surgical approach.

SHAPE. The thorax is a truncated cone, with its smaller base (superior) at the inlet, and its larger (inferior) at the diaphragm. The narrow, restricted and more rigid inlet affords ample protection to the important communicating structures between the thorax, neck and upper extremities, but leaves little room for obstructive pathologic processes. From the inlet to the base the thoracic cage assumes a gradually widening flare. The anterior bulge of the vertebral column makes the transverse section of the thoracic cavity kidney-shaped.

Early in life the anteroposterior and transverse diameters are about equal, making a rounded or barrel chest. In later life the shape

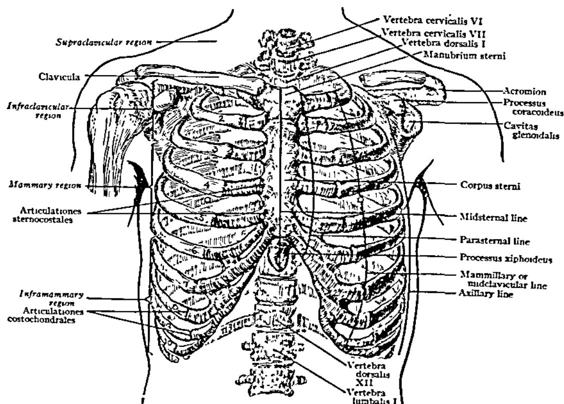


Fig. 231. ANTERIOR VIEW OF THE BONY THORAX TO SHOW REGIONS, LANDMARKS AND SURFACE MARKINGS.

becomes oval, owing to a widening of the transverse diameter. Any pathologic condition involving segments of the bony framework, especially if limiting its range of movement, tends to produce deformity with resulting changes in the shape and size of the cavity; to this deformity the visceral contents must conform. The elasticity and freedom of movement of the ribs result from their cartilaginous attachment to the sternum and to the slight movement at the vertebral joints. Serious damage to the chest contents may occur with no injury to the bony framework.

SURFACE ANATOMY. The circulatory and respiratory organs are ever the object of clinical examination and surgical approach, and knowledge of their topographic relations to the chest wall is of equal importance to physician and surgeon. Over the entire thorax the surface markings are conspicuous and readily palpable, making possible an easy comparative study of its two sides (Figs. 231, 232).

In examination important muscle groups must be distinguished, and the degree of their range of motion, laxity and rigidity must be noted with reference to disuse or paralysis. These groups include the spinal muscles lying in the trough between the vertebral column and the rib angles, and those to the shoulder girdle and upper arm. The crests of the angles of the ribs on either side are important markings in the study of curvatures of the spine.

Among the markings most useful for the thoracic projection of the enclosed viscera is a series of conventional *longitudinal lines* which parallel the long axis of the body. The midsternal line bisects the sternum and corresponds to the line of the midback; the midclavicular (mammary) line, dropped from the midpoint of the clavicle, usually passes somewhat mesial to the nipple; the parasternal line lies midway between the midclavicular and midsternal lines. The anterior, posterior and midaxillary lines are dropped from the anterior and posterior axillary folds and from the middle of the axillary space, while the scapular line

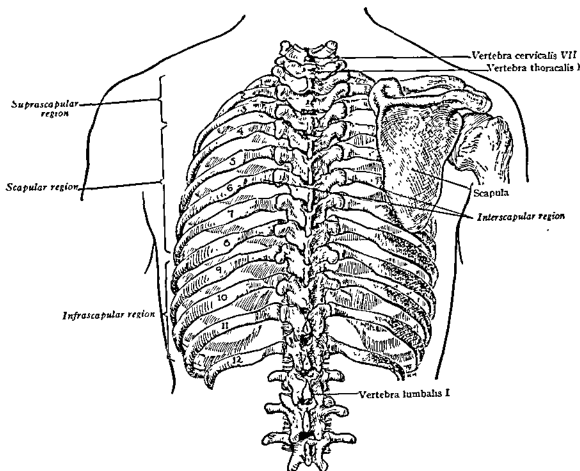


Fig. 232. POSTERIOR VIEW OF THE BONY THORAX TO SHOW THE REGIONS, LANDMARKS AND SURFACE MARKINGS.

runs through the apex of the inferior angle of the scapula. The *sternal angle* (of Ludwig) is the anterior bulge of the manubrium, or upper segment, with the body of the sternum.

DEFORMITIES. *Rickets* sometimes presents characteristic chest markings. An anterior projection of the sternum and costal cartilages, with sinking in or depression of the costal wall at the costochondral junction, is known as *pigeon breast*. There also may be beadlike enlargements formed at the costochondral junctions, known in aggregate as *rachitic rosary*. In *funnel chest* the inferior part of the sternum may be so sunken as almost to contact the vertebral column. The depressed sternum pulls down the inferior costal cartilages and rib ends.

Because of their firm vertebral attachments, the ribs are carried into deformity by functional and organic changes in the spine. Many chest deformities result from abnormal curvatures in the superior portions of the dorsal spinal column. In *kyphosis*, abnormal posterior curvature of the dorsal column, usually resulting from tuberculosis of the vertebral bodies, the superior spinal segment carries the corresponding ribs and sternum inferiorly, increasing the anteroposterior diameter of the thorax at the expense of the vertical and transverse measurements. In *scoliosis*, lateral curvature of the spine, the ribs, of necessity, follow the change in position and direction of the vertebral pedicles and laminae. Thus the curvature is increased on the side of the spinal convexity and diminished on that of the concavity. In structural scoliosis there is not only lateral deviation of the vertebrae, but also rotation or torsion about their longitudinal axes. The spinous processes incline toward the concavity of the curvature. On the side of the concavity the intercostal spaces are diminished, the ribs even being approximated; while on the side of the convexity the spaces are increased greatly. To these changes the thoracic viscera must adapt themselves.

CHAPTER 12

Thoracic Walls

Sternal Region

DEFINITION, DIVISION AND BOUNDARIES. The sternal region, occupying the median anterior thoracic wall, consists of the sternum with its three segments, named from above downward the *manubrium*, *body* (*gladiolus*) and *xiphoid* (*ensiform*) *process*, and the clavicular and chondral attachments (Fig. 231). The region extends superiorly to the jugular incisura (suprasternal notch), which forms the boundary between it and the infrahyoid region of the neck, and inferiorly to the epigastrium.

SURFACE ANATOMY. The superior margin of the sternum lies in the same horizontal plane as the inferior border of the body of the second thoracic vertebra, the distance separating them being about 5 cm. This is the inlet of the thorax. The junction of the manubrium and the body is a slight anterior prominence, the *angle of Ludwig*, which often can be seen and palpated and which lies on the same plane as the body of the fifth thoracic vertebra. The *xiphisternal junction* corresponds to the level of the cartilage between the ninth and tenth thoracic vertebrae.

The sternal contour is modified by fracture, dislocation and osteitis (tuberculous and syphilitic). The sternum is overlaid by a thin musculotendinous layer derived from the decussating fibers of origin of both major pectoral muscles superiorly, and by certain mesial fibers of origin of the abdominal recti inferiorly.

SKELETAL LAYERS. The spongy and vascular *sternum* is thickest at the upper extremity and gradually diminishes in thickness toward the xiphoid (Fig. 231). It is developed in two lateral halves, which, in their failure to unite, leave openings or foramina in the midsternal line, through which extrasternal infection may extend into the mediastinum.

The *sternoclavicular joints* are strengthened greatly by the *interclavicular ligament*, which stretches across the suprasternal space from one clavicle to the other (Fig. 233). Free movement of the clavicle on the sternum is afforded by the double synovial joint with its interposed articular disk. The shoulder girdles, which carry the upper extremities through their wide ranges of movement, are attached to the skeleton only through these joints, the unusual

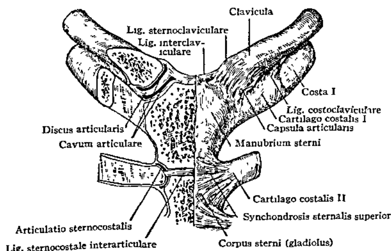


Fig. 233. STERNOCLAVICULAR AND STERNOCOSTAL JOINTS AND THEIR LIGAMENTS.

firmness and elasticity of which are shown by the infrequency of their dislocation and the exceedingly common occurrence of fracture of the clavicle. When the reinforcing ligaments are torn in exaggerated movements of the shoulder or by severe trauma, *dislocation* of the *inner end* of the *clavicle* occurs. The anterior variety of dislocation is the more usual, and does no harm to the great vessels, which normally lie behind the joint.

The superior seven pairs of costal cartilages extend to the lateral margins of the sternum, where they form *sternocostal joints*. Each joint is enclosed and reinforced by broad anterior and posterior sternocostal ligaments.

Surgical Considerations

FRACTURES AND INFECTION. Fracture of the sternum is rare, but, when present, occurs most frequently at the manubriogladiolar joint. Here the bone is thinnest and the skeletal attachments are most rigid. Fortunately, however, the ligamentous coverings protect the fragments so that compound injury is rare, and laceration of the mediastinal contents ordinarily is prevented. Advancing age, bringing complete ossification of the sternal pieces as well as of the costal cartilages, predisposes to fracture. The relatively superficial position and cancellous structure of the sternum expose it to trauma and infection. Syphilis and tuberculosis are relatively common.

CONGENITAL FUNNEL CHEST DEFORMITY. This deformity has been recognized for many years, but its adequate surgical correction is a relatively recent development. The primary defect (Fig. 234) seems to be maldevelopment of the anterior musculature of the diaphragm with a shortening of the central tendon which causes an unnatural pull on the sternum and lower ribs. The deformity produced usually displaces the heart to the left, though occasionally it is compressed in the midline or angulated to the right. The paradoxical movement of the chest, which is marked retraction with inspiration, is a most striking feature in infants and young children. The most prominent symptoms in infants are respiratory and gastrointestinal. They apparently exert a strenuous effort to breathe, and this interferes with digestive function so that feeding problems and persistent vomiting are common.

The "limited" operation done upon them consists in dividing the soft tissue attachments to the sternum and usually also cutting the shortened anterior portion of the central tendon of the diaphragm. Immediately after division of the attachments to the sternum, the baby's respiratory movements improve, and there are usually no more feeding problems.

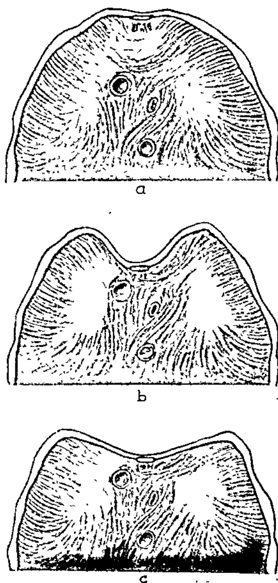


Fig. 234. PRIMARY DEFECT IN CONGENITAL FUNNEL CHEST DEFORMITY.

This is a maldevelopment of the anterior musculature of the diaphragm with a shortening of the central tendon which causes an unnatural pull on the sternum and lower ribs. *a*, Normal. *b*, Narrow type of deformity with thickened, tense substernal ligament and marked shortening of the central attachment of the diaphragm to the lower end of the sternum. *c*, Broad type of deformity with, in addition to the deformity of *b*, a shortening of the lateral anterior attachments of the diaphragm pulling in the lower ribs. (From Mahoney and Emerson: Arch. Surg., 67: 317–28, 1953.)

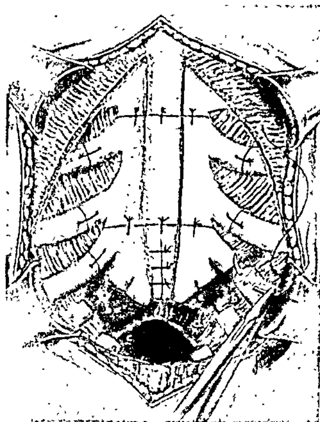


Fig. 235. COMPLETED PROCEDURE FOR CORRECTION OF CONGENITAL FUNNEL CHEST DEFORMITY.

Pectoralis major muscles have been reflected laterally, costal cartilages divided, posterior attachments of sternum incised, sternum cut across transversely between second and third interspaces, several osteotomies performed to allow molding of the sternum to its normal contour, excess cartilage resected, and the third and fourth cartilages usually resutured. The most important feature is the wide resection of the attachments of the sternum as far as the upper limit of the deformity. (From Mahoney and Emerson: Arch. Surg., 67: 317–28, 1953.)

The more complete operation, done on children over two years of age, is shown in Figure 235. Note the vertical and transverse osteotomies to allow molding of the sternum to its normal contour.

Costal Region

Definition and Boundaries. The costal region comprises the chest wall between the sternum and the vertebral column, and extends in depth to the parietal pleura. Among the extrinsic structures, the breast is of sufficient importance to merit a description under its own heading (p. 259).

Surface Anatomy. The rib cage is covered by much of the shoulder girdle and its connecting musculature. In the inferior and lateral portions of the region the digitations of the serratus muscles can be palpated. Examination for fractured or diseased ribs begins with the second rib, because it lies opposite the sternal angle of Ludwig, which is easy to determine, whereas the first, being tucked behind the inner extremity of the clavicle, is difficult to make out.

The *intercostal spaces* are wider in the anterior and superior portions of the chest than elsewhere, and their breadth is modified considerably in the movements of flexion and extension. Posteriorly, the intercostal vessels occupy a protected position in front of the ribs; they lie protected in their respective grooves in the inferior rib borders. Anteriorly, these vessels lie exposed in the intercostal spaces.

Extrinsic Musculature. The pectoralis major and minor and the serratus anterior form the extrinsic muscles on the anterior and lateral walls of the chest (Frontispiece, p. 245, and Fig. 236). The fan-shaped *pectoralis major*, of clavicular, sternocostal and abdominal origin, converges toward the proximal extremity of the arm, where it inserts mainly into the lateral lip of the intertubercular sulcus of the humerus. This muscle forms the anterior wall and fold of the axilla. The *pectoralis minor* is a thin, triangular muscle at the superior portion of the thorax under the pectoralis major. It arises from the third, fourth and fifth ribs near their cartilages and from their intercostal aponeuroses. The fibers insert into the coracoid process of the scapula. The nerve supply to both pectorals is from the anterior thoracic nerves (C 5, 6, 7, 8; T 1).

The *serratus anterior* (long thoracic nerve, C 5, 6, 7) occupies the side of the chest and medial wall of the axilla (Fig. 237). It is inserted mainly into the vertebral margin of the scapula. Contraction of this muscle draws the scapula forward on the chest wall. In beginning abduction of the humerus, it acts in association with the trapezius as a fixation muscle, and later is an active agent in the production of this movement. The movement of thrusting, as in fencing, is produced largely by the action of this muscle. It is the boxer's muscle, being the motive force in a forward punch. When the serratus is paralyzed or atrophied, the scapula no longer is held against the posterior chest wall, and the deformity of "winged scapula" results.

The large, triangular *trapezius muscle* (spi-

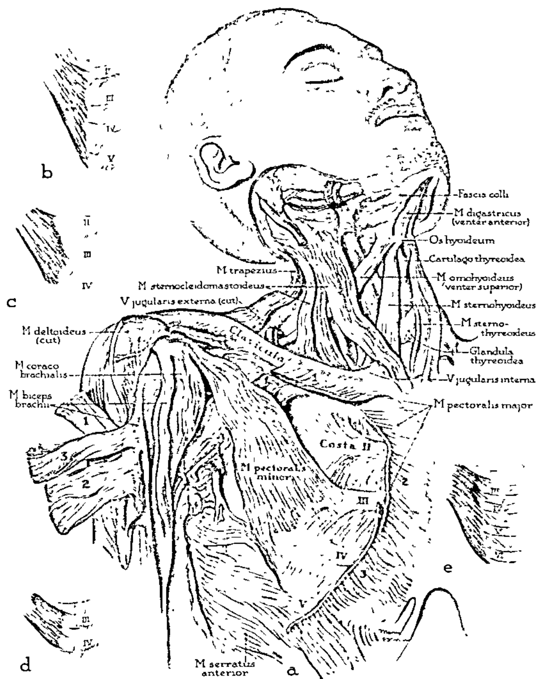


Fig. 236. ANATOMY OF THE PECTORAL AND RELATED REGIONS.

Deeper dissection of the specimen shown in the frontispiece (p. 246), together with examples of variation in the extent of origin of the pectoralis minor.

a, The dissection has been carried to ventral axillary level and, in the neck, to the level of the muscles which bound the cervical triangles. The pectoralis major muscle has been cut along its curving origin; the bands of insertion (numbered 1, 2 and 3) have been turned lateralward to show their attachments. In the axilla the cords and nerves of the brachial plexus, together with the axillary vessels, are partially removed from their sheath of combined adventitia and fascia. The lateral thoracic vessels are seen as they rest upon, and supply, the serratus anterior muscle. *b* to *e*, Types of origin of the pectoralis minor: from the second to the fifth ribs; from the second, third and fourth; from the third and fourth ribs; and from the third to the sixth. (From Anson, Jamieson, O'Conor and Beaton: Quart. Bull. Northwestern Univ. M. School, 27: 211-18, 1953)

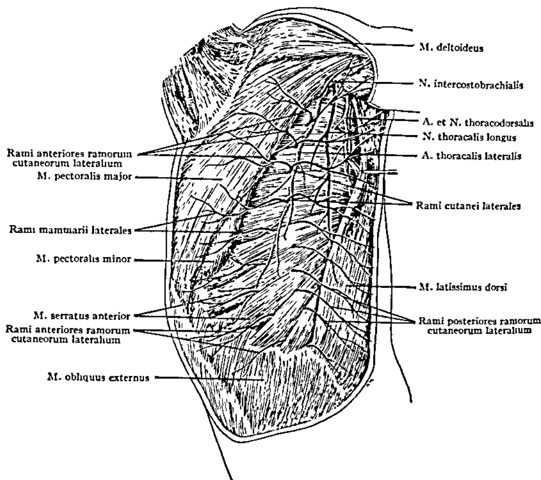


Fig. 237. LATERAL VIEW OF THE CHEST WALL TO SHOW THE EXTRINSIC MUSCLES, VESSELS AND NERVES.

nal accessory nerve and C 3, 4) overlies the upper part of the back. From an extensive origin along the cervical and thoracic spine, its muscle fibers converge toward the clavicle, acromion, and spine of the scapula (Figs. 238, 240).

The *latissimus dorsi* (C 6, 7, 8) is described on page 409.

The *major* and *minor rhomboid muscles* (C 5) are described on page 798.

INTRINSIC MUSCULO-OSSEOUS STRUCTURES. The upper seven ribs are *true* or *sternal ribs*, in that they terminate directly at the sternum (Figs. 231, 232). The lower five are *false*, having no direct attachment to the sternum. The first three false ribs, the eighth, ninth and tenth, are connected with the sternum through the intermedium of the cartilage of the seventh rib. The eleventh and twelfth ribs have neither direct nor indirect sternal attachment and are termed *floating ribs*.

The average width of the *intercostal spaces* is about 2 cm.; they are wider anteriorly than posteriorly, and are broader between the upper ribs than between the lower ones. The spaces are occupied by the intercostal muscles, vessels and nerves. The *intercostal muscles* are arranged in pairs, the internal and external, uniting the superior and inferior borders of adjacent ribs (Fig. 236).

VESSELS AND NERVES. Although there is an abundant vascular supply to the chest wall, there are no arteries of major size. The principal vessels are the intercostal and internal mammary arteries. The first two or three pairs of *intercostal arteries* arise from the superior intercostal branch of the costocervical trunk from the subclavian artery; the inferior nine pairs arise directly from the aorta. The location of the artery in the subcostal groove (Fig. 229) on the dorsal and dorsolateral chest wall explains the necessity of proceeding along the superior rib margin in aspiration of pleural exudates and in surgical approach through the interspaces. This bony bed and its vascular contents explain the danger of vessel injury in rib fracture.

The *internal mammary branch* of the sub-

M. splenius capitis et cervicis
M. sternocleido-mastoideus
M. trapezius
M. infraspinatus
M. deltoideus
Spina scapulae
M. triceps brachii
M. teres major
M. rhomboideus major
M. latissimus dorsi

Fig. 238. MUSCLES OF THE BACK, NECK AND SHOULDER.

The first layer of muscles of the back is shown, in relation to the musculature of the upper extremity.

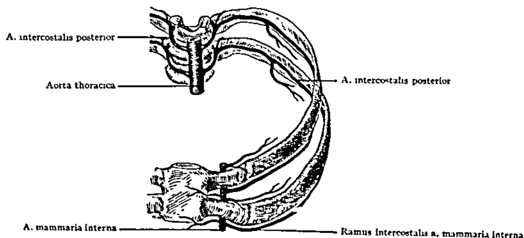


Fig. 239. OBLIQUE CROSS SECTION SHOWING THE RELATIONS OF THE INTERCOSTAL ARTERIES TO THE RIBS AND INTERCOSTAL SPACES.

Posterior to the axilla, the arteries are protected; anterior to the axilla, they are more exposed.

clavian artery passes inferiorly, anteriorly and mesially on the pleura. It lies behind the sternal extremity of the clavicle, and descends into the chest along the lateral margin of the sternum, parallel to and about 1.25 cm. from it. At the level of the sixth intercostal space the artery divides into a lateral branch, the *musculophrenic*, and a medial terminal branch, the *superior epigastric* (p. 360).

Injury to the internal mammary artery may result rapidly in a fatal hemorrhage. Although it can be ligated fairly readily in the first three or four intercostal spaces, it is difficult to ligate in the fourth or fifth space because of the narrowness of these intervals.

Although the cervical and brachial plexus partially supply the extrinsic musculature, the *intercostals* are the main *nerve supply* of the muscles of the chest wall. Irritation of the intercostal nerves produces symptoms of *intercostal neuralgia*, which is difficult to differentiate from pleurisy.

Surgical Considerations

RIB FRACTURE. Because of the curve, intrinsic elasticity and extensive muscle attachment of the ribs, compression fracture is unusual, but may occur from severe anteroposterior compression of the chest. The break is likely to be directed outward at the apex of the main curve and, for this reason, rarely injures the pleura. Frequently, however, ribs are broken by direct violence, the site of fracture being at the point of injury. In such trauma the fragments may injure the pleura and the intercostal vessels, with resulting hemothorax and, occasionally, subcutaneous emphysema.

The more exposed ribs, the fourth to the eighth, are most likely to be injured by direct violence. Fractures occur more often in adult life than in childhood, owing to the loss of elasticity incident to increasing calcification of the costal cartilages. Little, if any, shortening or displacement occurs with fracture, because of the fixation of both extremities of the ribs and the attachment of the intercostal muscles. *Treatment* of rib fracture aims at immobilization of the injured part of the chest wall to alleviate pain and favor healing. Immobilization is effected by strapping in the general horizontal direction of the ribs.

INTERCOSTAL THORACOTOMY. Intercostal thoracotomy consists in opening into the pleural cavity through an intercostal space. Intercostal thoracotomy is not simpler than thoracotomy through the bed of an excised rib. There is much more danger of wounding the intercostal vessels in the intercostal incision. Thoracotomy through the bed of an excised rib is preferable when complete pneumonectomy is to be done, because an airtight closure is possible. This can rarely be accomplished when an intercostal incision is used. Intercostal thoracotomy is best in younger patients.

Closed drainage through an intercostal thoracotomy incision for empyema is much less used now because of the use of antibiotics. If necessary, the site of incision depends upon the lower level of the fluid to be drained, as determined by an exploratory puncture. The eighth or ninth interspace about the lower scapular line is selected for entrance, since it is sufficiently low to insure noninterference with the scapula and yet high enough to avoid the inadequate drainage which frequently accompanies incision into the costophrenic sinus. The trocar is passed close to the upper border of the lower rib in order to avoid the intercostal vessels and nerve (Fig. 241).

THORACOTOMY THROUGH THE BED OF ONE OR MORE SUBPERIOSTEALLY EXCISED RIBS. The operation usually performed for evacuation of a purulent pleural effusion uses an incision in the bed of a rib, part of which has been excised subperiosteally. Simple rib resection contemplates the removal of part of one rib, but the unusual case demands partial excision of several. For a well defined collection of pus, incision should be made directly over the suspected area. When fluid is free in the pleural cavity, the operative site generally chosen is the bed of the sixth and seventh ribs in the posterior or midaxillary line.

OPERATIONS FOR CHRONIC EMPYEMA IN GENERAL. In chronic nontuberculous empyema, in which the lung is compressed and collapsed by the pressure of intrapleural fluid, radical surgical intervention is necessary. The pleural infection causes the lung to be covered and bound down by a dense inflammatory membrane of varying denseness and thickness. In the presence of an exudate of this kind, expansion of the lung is lost, even after evacuation of the effusion. In addition to a collapsed and restricted lung, a pleural dead space results, which is difficult to disinfect and obliterate.

Two general surgical procedures contem-

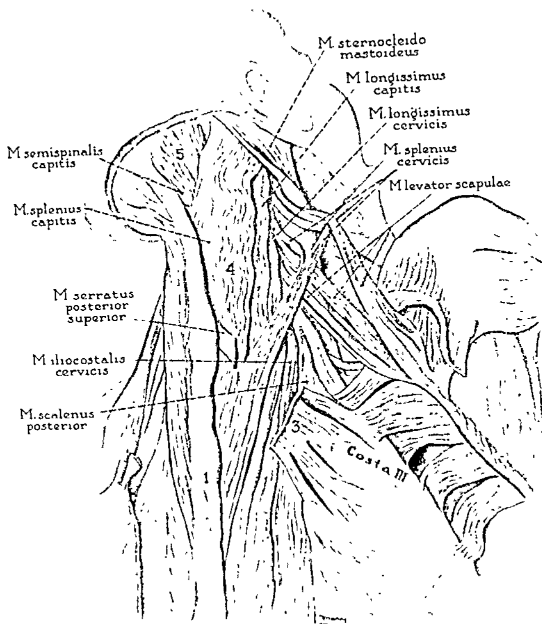


Fig. 240. DEEP MUSCLES OF THE BACK, NECK AND SHOULDER.

The midportion of the serratus posterior superior muscle (at 3) has been excised to expose the cervical and capital parts of splenius (4); these muscles, as shown, are cranial continuations of the sacrospinalis. The semispinalis capitis (5) lies next beneath the splenius. Compare Figure 226.

plate the approximation of the lung surface and the chest wall with elimination of the pus-secreting dead space (Fig. 242). *Pulmonary decortication*, which endeavors to mobilize the lung, imprisoned against the mediastinum by dense plastic exudate, is used for both tuberculous and nontuberculous chronic empyema. This operation is performed through a major thoracotomy exposure (Figs. 291, 292), and the layers of organized exudate gathered on the visceral pleura are freed by multiple incisions or are detached. When this layer has been freed sufficiently, the lungs gradually expand and fill the pleural cavity.

Thoracoplasty, the second procedure used to obliterate an empyema space of either tuberculous or nontuberculous type, is a poor substitute for decortication. Sometimes decortica-

tion cannot be accomplished, more commonly in chronic tuberculous empyema, and in this event thoracoplasty is an acceptable substitute. Thoracoplasty is used to obliterate chronic empyema after pneumonectomy (Fig. 243).

INFECTION OF THE RIBS. Tuberculosis and typhoid fever sometimes cause osteitis in the ribs, and syphilis may cause periostitis. Localization here may be the result of repeated traumatism to which the ribs are exposed because of their subcutaneous position. Osteitis of the rib ends may occur after rib resection for empyema, with infection traveling in the intercostal muscle planes.

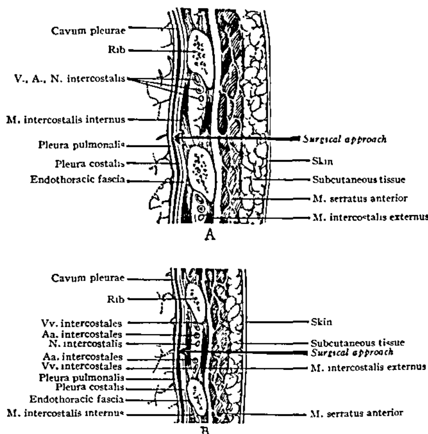


Fig. 241. VERTICAL SECTIONS THROUGH THE RIBS AND INTERSPACES.

A, Posterior to axilla; *B*, anterior to axilla. To show the differences in the location of the intercostal vessels and nerves and the importance of these relations in intercostal thoracotomy.

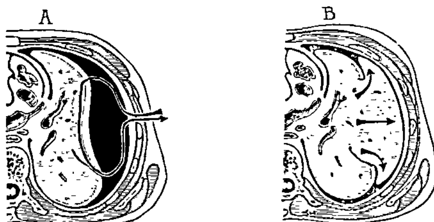


Fig. 242. OPERATION OF PULMONARY DECORTICATION.

A, Visceral pleura being excised through an intercostal incision; *B*, released lung expanding to fill the chest cavity. (Modified after Testut and Jacob.)

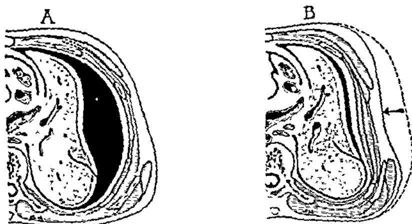


Fig. 243. PRINCIPLES UNDERLYING THORACOPLASTY.

A, Large dead space between the thickened layers of visceral and parietal pleura; *B*, resection of a number of ribs allows the chest wall to fall in and obliterate the dead space. (Modified from Testut and Jacob.)

Breast or Mammary Region

The breast consists embryologically and morphologically of a group of exceedingly highly specialized cutaneous glands, and therefore is a constituent element of the superficial layers of the costal region. Its function in the female, the frequency of breast lesions, and the importance of the lymphatic extension in the latter warrant special consideration.

DEFINITION AND BOUNDARIES. The mammary gland, with its fibrous and fatty tissue, occupies the interval between the third and seventh ribs, and extends in breadth from the parasternal to the midaxillary line. Surgically, the region extends in depth through the major and minor pectorals to the intercostal musculature, since lymphatic extension pervades these muscles. The glandular tissue rests in great part upon the pectoral fascia, and to a less degree upon the serratus anterior muscle. Breast tissue often extends into the anterior axillary fold. This axillary prolongation may be visible as a definite mass (Fig. 244) simulating an axillary tumor or may be the seat of either benign or malignant tumors.

SURFACE ANATOMY. The shape and degree of development of the breast vary with the person, the period of function, and age. The glandular portion in the male usually remains undeveloped, and there is little surrounding adipose tissue, the result being that the male breast is flat and insignificant. The size of a breast is no true indication of its ability to secrete, since fatty tissue makes up most of the bulk of the organ. The virginal breast is almost hemispherical, but is somewhat flattened above the nipple. In multiparae the breasts become large and lax, and rarely regain their former shape and consistency. A shriveled breast indicates merely a disappearance of fat, since the gland still may be active functionally. After the menopause much of the glandular tissue atrophies.

DEVELOPMENT AND CONGENITAL ABNORMALITIES. The breast develops from invaginated ectoderm at the point where later the nipple is formed. About the middle of fetal life the mammary buds branch out into the superficial fascia, which condenses about the gland. By this enlargement the mammary gland (Fig. 245) pushes aside the fatty tissue and comes to rest upon the fascia covering the underlying pectoral muscle.

In the young child the breast structure consists almost entirely of a number of branching ducts with but little glandular tissue, the periglandular structures being connected with the skin by fibrous septa. As puberty is reached the rudimentary gland buds grow rapidly and multiply, with resulting formation of acini and gland lobules. During pregnancy there is a marked increase in gland development with corresponding diminution in the interglandular tissue, and the basal part of the breast comes into relationship with the subjacent pectoral muscles.

Imperfect development of the breast, evidenced by *absence of the nipple*, is an abnormality which may be present even with glands of normal development. In such instances the ducts open on a depression at the site of the

nipple in the center of the areola. Defective development of the nipple commonly takes the form of excessive shortness; or, though fairly well formed, it may be surrounded by a deep fossa. Both these defects tend to render nursing difficult.

Supernumerary breasts (*polymastia*) are of interest from the standpoint of excessive development. In certain mammalian embryos there is, on each side of the ventral aspect of the median line, a distinct ectodermic ridge which extends from the axillary region to the groin (inguino-axillary line). While there is some doubt whether similar epiblastic ridges are present in the human embryo, the occasional presence of supernumerary mammary glands or nipples makes their existence appear probable. Their position, when present in the human subject, appears as a rule to correspond to the direction of these lines, the most common location for a supernumerary gland being inferior and mesial to the gland, between it and the umbilicus. Four well developed actively secreting breasts have been observed, the two extra ones being located in the axillae. Accessory breasts usually are imperfect, the nipple alone being present in a rudimentary state, closely resembling a pigmentary spot or small nevus. A supernumerary gland rarely is present without a nipple; when it occurs, it can be explained most readily as a reversion to an ancestral type.

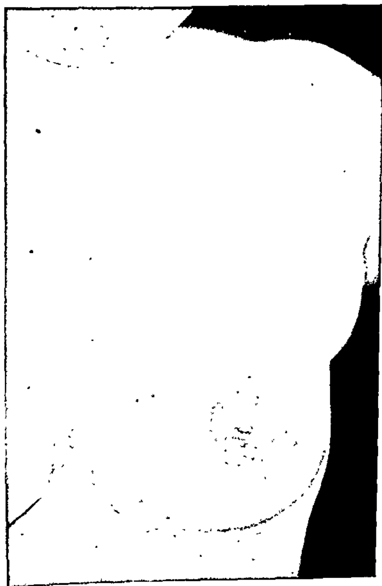


Fig. 244. AXILLARY PROJECTION OF THE LEFT MAMMARY GLAND.
(From Haagensen: Diseases of the Breast.)

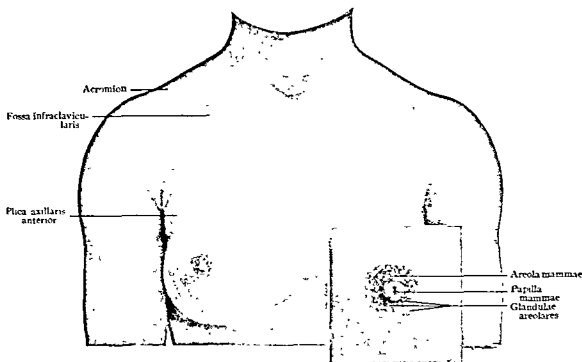


Fig. 245. BREAST REGION IN A YOUNG ADULT FEMALE.

STRUCTURE. The SKIN over the center of the breast is modified to form the areola and nipple (Fig. 245). The circular *areola*, a cutaneous zone about 5 cm. in diameter, has many minute rounded elevations, indicating the presence of underlying cutaneous glands. These *areolar glands* (of Montgomery) are isolated sebaceous glands for lubrication of the nipple during lactation.

The color of the nipple and areola varies with the complexion of the person, but in young subjects usually is rose pink. During pregnancy the color becomes browner; the pigmentation never entirely disappears, and increases slightly with each succeeding gestation. The areola may be the location of fissures, eczema or abscess from infection in the areolar glands. The skin of the nipple is so delicate that trauma, to which it is frequently subjected, often causes fissure-like abrasions. These openings are portals of entry for infection in the deeper glandular tissue. In nursing, pain accompanying nipple abrasion is so intense that it may be necessary to take the child from the breast.

The *nipple*, or papilla mammae, a conical or wartlike elevation, is located in the middle of the areola on the approximate summit of each breast. In the young breast the nipple usually lies opposite the fourth intercostal space, but after lactation the breast becomes pendant and the nipple no longer is a guide to intercostal spaces. By the action of the circular fibers at the base of the nipple and the longitudinal fibers attached to the lactiferous ducts, the nipple protrudes spontaneously upon touch. This phenomenon of erection, commonly attributed to the action of cavernous tissue within the nipple, probably is entirely muscular.

Beneath the skin is the areolo-fatty SUBCUTANEOUS TISSUE, within which lie the glandular elements of the breast. The superficial fascia not only forms a general covering for the secreting apparatus, but also sends into it partitions which aid materially in supporting the glandular as well as the fatty elements. Each duct is surrounded by an area of periductal connective tissue with attachments to the skin. These fibrous extensions with attachments to the skin were described by Sir Astley Cooper and became known as "Cooper's ligaments" (Fig. 246). When carcinoma invades any glandular area, the skin over the area is retracted, since the periductal strands of connective tissue fail to lengthen with the enlargement of the gland. Sir Harold Stiles showed that the parenchyma of the breast is prolonged peripherally along these Cooper "ligaments" to almost reach the corium. From this he concluded "that the surgeon who intends to excise the whole of

nipple in the center of the areola. Defective development of the nipple commonly takes the form of excessive shortness; or, though fairly well formed, it may be surrounded by a deep fossa. Both these defects tend to render nursing difficult.

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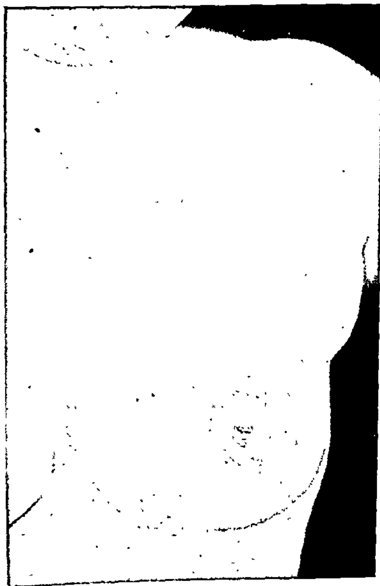


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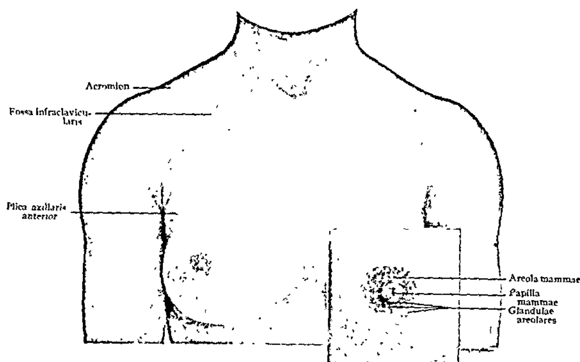


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STRUCTURE. The SKIN over the center of the breast is modified to form the areola and nipple (Fig. 245). The circular *areola*, a cutaneous zone about 5 cm. in diameter, has many minute rounded elevations, indicating the presence of underlying cutaneous glands. These *areolar glands* (of Montgomery) are isolated sebaceous glands for lubrication of the nipple during lactation.

The color of the nipple and areola varies with the complexion of the person, but in young subjects usually is rose pink. During pregnancy the color becomes browner; the pigmentation never entirely disappears, and increases slightly with each succeeding gestation. The areola may be the location of fissures, eczema or abscess from infection in the areolar glands. The skin of the nipple is so delicate that trauma, to which it is frequently subjected, often causes fissure-like abrasions. These openings are portals of entry for infection in the deeper glandular tissue. In nursing, pain accompanying nipple abrasion is so intense that it may be necessary to take the child from the breast.

The *nipple*, or papilla mammae, a conical or wartlike elevation, is located in the middle of the areola on the approximate summit of each breast. In the young breast the nipple usually lies opposite the fourth intercostal space, but after lactation the breast becomes pendant and the nipple no longer is a guide to intercostal spaces. By the action of the circular fibers at the base of the nipple and the longitudinal fibers attached to the lactiferous ducts, the nipple protrudes spontaneously upon touch. This phenomenon of erection, commonly attributed to the action of cavernous tissue within the nipple, probably is entirely muscular.

Beneath the skin is the areolo-fatty SUBCUTANEOUS TISSUE, within which lie the glandular elements of the breast. The superficial fascia not only forms a general covering for the secreting apparatus, but also sends into it partitions which aid materially in supporting the glandular as well as the fatty elements. Each duct is surrounded by an area of periductal connective tissue with attachments to the skin. These fibrous extensions with attachments to the skin were described by Sir Astley Cooper and became known as "Cooper's ligaments" (Fig. 246). When carcinoma invades any glandular area, the skin over the area is retracted, since the periductal strands of connective tissue fail to lengthen with the enlargement of the gland. Sir Harold Stiles showed that the parenchyma of the breast is prolonged peripherally along these Cooper "ligaments" to almost reach the corium. From this he concluded "that the surgeon who intends to excise the whole of

nipple in the center of the areola. Defective development of the nipple commonly takes the form of excessive shortness; or, though fairly well formed, it may be surrounded by a deep fossa. Both these defects tend to render nursing difficult.

Supernumerary breasts (*polymastia*) are of interest from the standpoint of excessive development. In certain mammalian embryos there is, on each side of the ventral aspect of the median line, a distinct ectodermic ridge which extends from the axillary region to the groin (inguino-axillary line). While there is some doubt whether similar epiblastic ridges are present in the human embryo, the occasional presence of supernumerary mammary glands or nipples makes their existence appear probable. Their position, when present in the human subject, appears as a rule to correspond to the direction of these lines, the most common location for a supernumerary gland being inferior and mesial to the gland, between it and the umbilicus. Four well developed actively secreting breasts have been observed, the two extra ones being located in the axillae. Accessory breasts usually are imperfect, the nipple alone being present in a rudimentary state, closely resembling a pigmentary spot or small nevus. A supernumerary gland rarely is present without a nipple; when it occurs, it can be explained most readily as a reversion to an ancestral type.

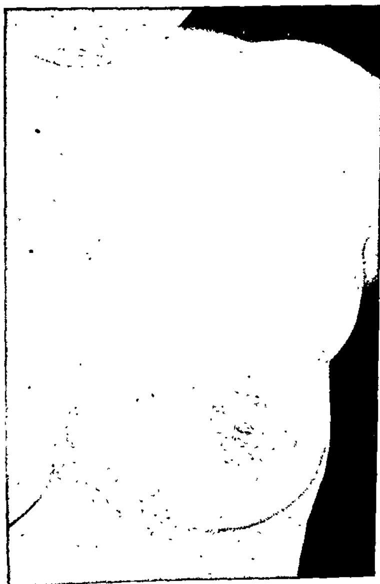


Fig. 244. AXILLARY PROJECTION OF THE LEFT MAMMARY GLAND.
(From Haagensen: Diseases of the Breast.)

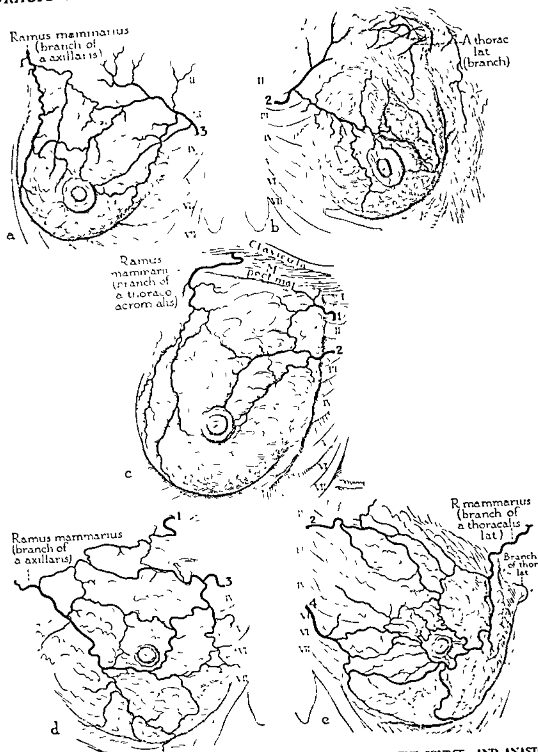


Fig. 247. ARTERIAL SUPPLY OF THE MAMMARY GLAND; VARIATIONS IN THE SOURCE, AND ANASTOMOTIC PATTERN OF THE VESSELS.

Perforating branches of the internal mammary are numbered (1 to 4). *a* and *b*, Both glands of a specimen; *c*, right gland of a second specimen; *d* and *e*, both glands of a third specimen.

The larger vessels are at first virtually subcutaneous, their branches then penetrate the glandular tissue (see *b*). Near the nipple the anastomosis is sometimes circumareolar (see *e*). (From Carr, Bishop and Anson: Quart. Bull. Northwestern Univ. M. School, 16: 150–54, 1942.)

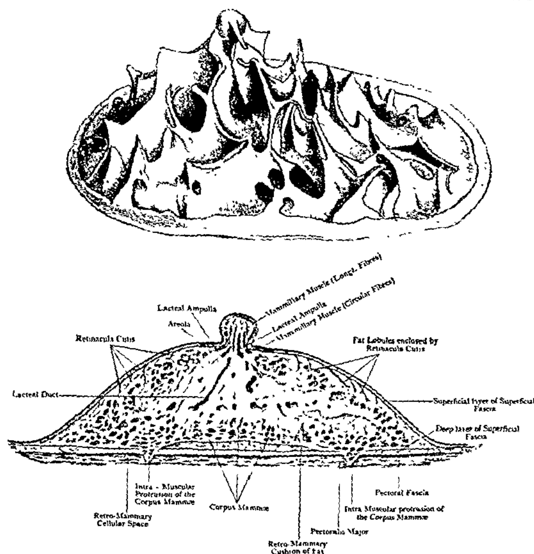


Fig. 246. LIGAMENTOUS AND FASCIAL STRUCTURES OF THE BREAST.

Above, Cooper's ligaments of the breast. (From Sir Astley Cooper: The Anatomy and Diseases of the Breast. Philadelphia, Lea & Febiger, 1845.) *Below*, Fascial relationships of the breast (diagrammatic) Note intramuscular protrusion of corpus mammae beneath the deep layer of the superficial fascia. A complete removal of mammary parenchyma would require the excision of a thin layer of underlying muscle. (From Cecil H. Leaf: Cancer of the Breast: Clinically Considered. London, Constable.)

such a gland (the breast) must either sacrifice a large amount of skin or keep so close to it in dissecting it off the mamma as to run some risk of sloughing."

The blood vessels of the breast as well as the glandular tissue *are supported by the connective tissue network*, which, when taut, gives firmness and contour to the virgin breast. During lactation it undergoes varying degrees of softening and atrophy as the glandular elements increase. After parenchymal retrogression and some diminution in fat the pendulous breasts of the multipara appear.

Between the mammary gland and the pectoralis major muscle lies the deep layer of superficial fascia. As shown in Figure 246, part of the secreting structure of the breast may penetrate this fascia; thus a complete mastectomy requires the removal of at least a superficial portion of the pectoralis major muscle.

The SECRETING PARENCHYMA of the gland *consists of a dozen or more separate irregular lobes* which radiate from the nipple. Each lobe has its own excretory duct which converges toward the nipple, where it opens. Part of the secreting structure may lie deep to the pectoral fascia in the retromammary layers. To avoid the greatest number of breast radicles, radial incisions are made in drainage of *suppurative mastitis*, especially when abscesses are located near the base of the nipple. The subcutaneous connective tissue divides the lobes into lobules,

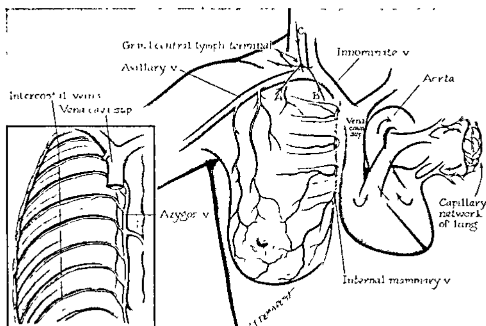


Fig. 249. THE 3 DEEP VENOUS ROUTES FROM THE BREAST AND CHEST.
These are avenues of metastasis from carcinoma of the breast to the lungs. (From Haagensen: Diseases of the Breast).

lying skin. Those rami which reach the mammary gland at first course superficially in the fatty tissue; ultimately, however, they attain deeper level (Fig. 247, *b*, *e*). They tend to converge upon the nipple (Fig. 247, *e*); en route they anastomose not only with vessels from neighboring intercostal spaces, but also with those derived from axillary and subclavian sources.

The arteries of mammary supply which are derived from the thoraco-acromial branch of the axillary artery or from the latter vessel directly first supply the pectoral muscles (Fig. 248). Perforating the pectoralis major and pectoralis minor, and thereby attaining a superficial level just below the clavicle, the arteries usually descend vertically to the nipple.

Vessels of a third group come from the axillary artery or from its lateral thoracic branch. Whatever the source may be, the derived mammary rami follow a circumflex course; that is, they turn around the axillary border of the pectoralis major muscle either to pass directly forward upon the gland or to descend first along its lateral margin.

The three groups of deep veins carrying blood from the breast are shown in Figure 249 and are of special interest because they are vascular routes for tumor emboli from the breast to the lungs. (1) *Perforating branches of the internal mammary vein* are the largest veins draining the breast. They are readily seen coming through rib interspaces and are divided after clamping during a radical mastectomy. Emptying finally into the innominate veins, thence to the pulmonary capillary network, they are easy routes for metastatic carcinomatous emboli to the lungs. (2) *The axillary vein* is variable in size and may even be double. It has many inconstant tributaries from the chest wall, pectoral muscles and breast. Leading to the pulmonary network, they are a second route to the lungs for carcinomatous emboli. (3) *The intercostal veins*, one of the most important routes of venous drainage from the breast, travel posteriorly to the vertebral veins and thence to the azygos veins and the superior vena cava. They are a third pathway from the breast to the lungs.

The vertebral system of veins is a separate system paralleling the caval system. It drains not only the vertebrae, but also the bones of the pelvis, upper ends of the femurs, the shoulder girdle, upper ends of the humeri and the skull. Batson emphasizes that this system provides an easy venous pathway whereby metastases escaping through the intercostal veins may spread to the skeleton.

Lymphatic Drainage of the Breast. A knowledge of the lymph drainage of the breast is extremely important because breast cancer commonly spreads along such channels. The

and these into the ultimate secreting units, the alveoli. Each lactiferous duct, as it approaches the base of the nipple, presents a fusiform or ampullary enlargement, the lactiferous sinus, which acts as a temporary reservoir for the secretion of the gland. The duct narrows beyond the enlargement and passes into the nipple.

Blood Supply of the Breast. The arteries of supply to the mammary gland are derived from the following sources: the perforating rami of the internal mammary; the lateral thoracic branch of the axillary; direct mammary rami from the axillary; branches of subclavicular course from the thoraco-acromial.

The vessels of supply to the gland which are derived from the internal mammary artery course medialward from parasternal position. Although the corresponding perforating rami are regularly given off by the internal mammary artery to the uppermost six of the intercostal spaces, usually only two of the six furnish mammary rami. The first, second and third are the most frequent sources; the common number supplied to a gland is two (Fig. 247). The perforating rami, after piercing the intercostal musculature, supply the pectoralis major muscle and send branches to the over-

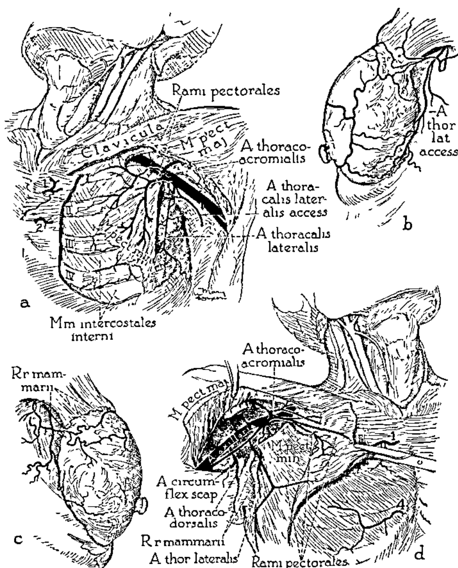


Fig. 248. ARTERIAL SUPPLY OF THE MAMMARY GLAND (CONTINUED).

The arteries which attain the gland from the lateral aspect descend as a pedicle, leaving the axillary space by passing around the free border of the pectoralis major muscle. Those which reach the gland from the superior position perforate the pectoralis major. The arteries which first supply the medial portion of the mammary gland must first perforate the internal intercostal muscles in parasternal position. (From Anson, Wright and Wolfer: Surg., Gynec. & Obst., 69: 468-73, 1939)

the costocoracoid fascia and terminate in the axillary lymph nodes.

There are two accessory routes of lymphatic drainage from the breast to the nodes at the apex of the axilla, and these are also shown in Figure 251.

1. *The transpectoral route* begins as a retromammary plexus in the loose areolar tissue between the pectoral fascia and the breast, perforates the pectoralis major and, following the course of the pectoral branch of the thoracoacromial artery, empties into the subclavicular group of axillary lymph nodes. Lymph nodes of this route lying between the pectoralis major and minor muscles have been called "Rotter's nodes," because in studying operative specimens of carcinoma of the breast in which the pectoral muscles had been removed Rotter found metastatically involved nodes on the posterior aspect of the pectoralis major muscles or within its substance.

2. *The retropectoral route* is a lymphatic pathway found in about one third of subjects and drains the superior and internal portions of the breast. It runs laterally to round the outer edge of the pectoralis major and then runs upward on its under surface, or under the pectoralis minor, to the apex of the axilla, where it empties into the subclavicular group of nodes. This retropectoral group is a more direct pathway to the subclavicular nodes than the main lymphatic route through the external mammary and central group of axillary lymph nodes, and Haagensen considers it to offer one explanation for the bad prognosis of carcinoma situated in the upper inner aspect of the breast.

Concerning the axillary lymph nodes, Mornard divides them into five principal groups which are shown in Figure 251. These nodes lie beneath the costocoracoid fascia along with the axillary blood vessels, nerves, connective tissue and fat and are held within a delicate yet strong fascial network which makes dissection in one mass relatively easy. The average number found in each location by Pickren from a careful dissection of cleared technique specimens is noted.

1. *The external mammary group* lies along the medial wall of the axilla, outside of or in the fascia covering the digitations of the serratus anterior muscle from the sixth rib to the axillary vein, following the course of the lateral thoracic vein. Average number found was 1.4.

2. *The subscapular group* lies along the subscapular and thoracodorsal blood vessels and extends from the lateral thoracic wall to the axillary vein. Average number found was 6.3.

3. *The central group* is the second most numerous, and, being the largest of the axillary nodes, are the ones most frequently felt. They

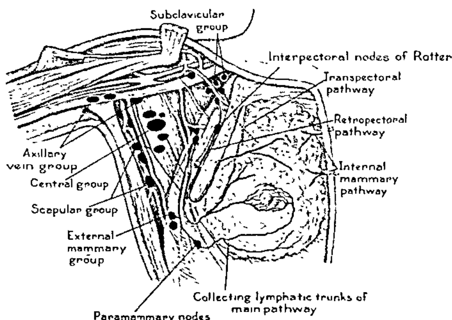


Fig. 251. THE PATHWAYS OF LYMPHATIC DRAINAGE FROM THE BREAST.
(Modified by Haagensen: Diseases of the Breast. From Rouvière, Anatomie des lymphatiques de l'homme. Paris, 1932.)

subject has been well presented by Haagensen* from whose book much of the following is extracted.

The breast is an ectodermal structure and a specialized organ of the skin. The rich lymphatics of its dermis are intimately connected with the deep lymphatics of the underlying fascial plane. From the dermal lymphatics (Fig. 250) Haagensen emphasizes two points: (1) the striking lymphatic flow to the axilla from the whole upper anterolateral chest. (2) At the level of the umbilicus lymphatic tributaries diverge so that chest and upper abdominal wall drainage goes to the axilla, and lower abdominal wall drainage passes to the groin. A carcinoma of the breast involving the skin, even of the inframammary region, drains into lymphatics running to the axilla and not the groin.

In the subareolar area there is a particularly numerous meshwork of lymphatics (Fig. 252) which widens peripherally to form a dense circumareolar plexus. From this, according to Rouvière, enormous external and internal trunks (Fig. 251) are the main routes of lymphatic drainage from the breast to the axilla. (1) *The external trunk* passes from the subareolar plexus to the outer border of the pectoralis major and receives collaterals from the upper half of the breast. (2) *The internal trunk* from the medial edge of the subareolar plexus runs downward and then laterally to reach the outer border of the pectoralis major. It receives tributaries from the lower half of the breast. Both these trunks pass around the outer edge of the pectoralis major muscle, then penetrate

* Haagensen, C. D.: Diseases of the Breast. Philadelphia, W. B. Saunders Company, 1956.

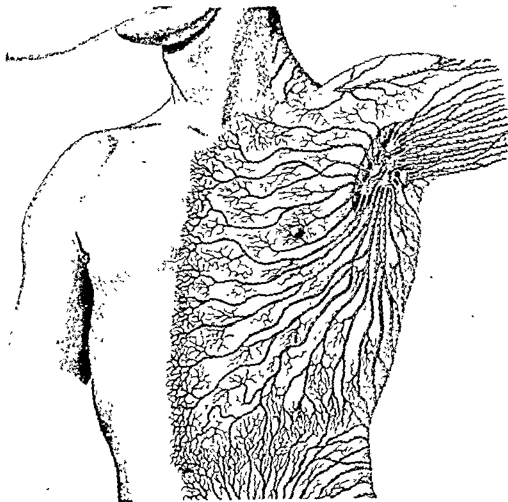


Fig. 250. THE LYMPHATICS OF THE SKIN OF THE ANTERIOR LATERAL CHEST WALL DRAIN TO THE AXILLARY NODES.

(Sappey. Haagensen: Diseases of the Breast.)

vein and upon the brachial plexus. These are the most easily palpable of the supraclavicular nodes involved by carcinoma from the breast, and the belief is that such extension is almost always due to retrograde permeation from the sentinel nodes rather than by a direct pathway superficial to the clavicle from the upper portion of the breast.

As stated before, involvement of the supraclavicular nodes by carcinoma from the breast makes the prognosis particularly poor, since their close relation to the venous system renders distant metastases to viscera or bone almost certain.

Lymphatic Drainage from the Breast to the Internal Mammary Nodes. From a study of the spread of breast carcinoma early in this century, the British surgeon, W. Sampson Handley, became interested in the internal mammary route. It was soon learned that the central and medial lymphatics of the breast pass medially along the course of the blood vessels perforating down through the pectoralis major muscles and empty into the internal mammary chain of nodes situated in the interspaces between the costal cartilages, within 3 cm. of the sternal edge. As shown in Figure 253, these nodes are in close proximity to the internal mammary vessels and lie on the endothoracic fascia. They are small nodes, 1 to 2 mm. usually and occasionally 5 to 6 mm. in diameter, and, according to Ju, average 6.2 per subject. He found the greatest concentration in the upper three interspaces. Arão and Abrãe found an average of 16.2 nodes per subject, and also found in 21 per cent of their subjects retromanubrial nodes at the level of the first interspace connecting the right and left internal mammary chains (Fig. 254).

These internal mammary lymphatic trunks eventually empty into the great veins by one of several routes very similar to that of the subclavicular group of nodes. On the left side they may empty into the thoracic duct, and on the right side into the right lymphatic duct. On either side they may terminate in the lowest lymph node of the inferior deep cervical group and thence into the great veins, or finally they may empty directly into the jugular-subclavian confluence (Fig. 255).

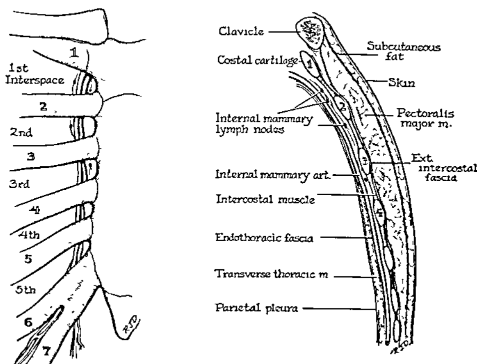


Fig. 253. THE INTERNAL MAMMARY LYMPHATICS.
(From Haagensen: Diseases of the Breast.)

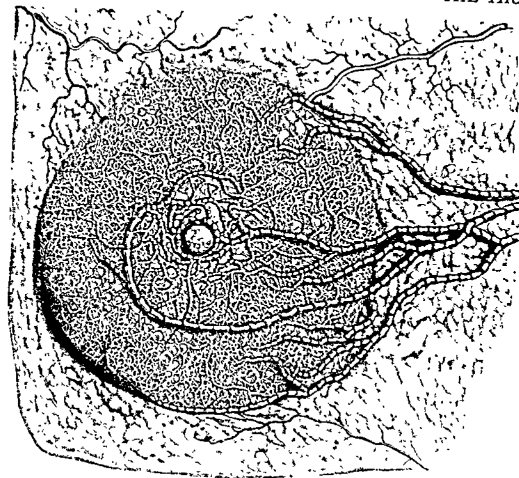


Fig. 252. RICH SUBAREOLAR LYMPHATIC PLEXUS.
(Sappey. Haagensen: Diseases of the Breast)

lie embedded in the fat in the center of the axilla. Average number found was 11.2.

4. *The axillary vein group* is the most numerous and lies along the lateral portion of the axillary vein. Average number found was 13.2.

5. *The subclavicular group* lies at the high apex of the axilla where the subclavian vein disappears beneath the subclavius muscle. The collecting trunks from all other axillary nodes empty into these subclavicular nodes, and from them large efferent lymph vessels pass upward beneath the clavicle for a distance of about 3 cm. to terminate in three possible ways: (1) directly into the venous system at the junction of the subclavian and the jugular; (2) joining with the jugular and bronchomediastinal lymphatic trunks to form a common duct emptying into the jugular-subclavian venous confluence; (3) emptying into sentinel nodes of the supraclavicular inferior deep cervical group close to the jugular-subclavian junction. Consistent with the close proximity of the subclavicular group of nodes and the venous system (Fig. 255), Haagensen's experience is that if these highest of axillary nodes are involved with metastases from breast carcinoma, a radical mastectomy is not curative, the patient usually harboring visceral or bone metastases.

The Supraclavicular Lymph Node Group. As mentioned in the previous paragraph, the third possible termination of the efferent trunks from the subclavian nodes may drain to the sentinel group of nodes in the supraclavicular area near the confluence of the internal jugular vein and the subclavian vein. These nodes lie deeply beneath the lateral edge of the lower end of the sternocleidomastoid muscle behind the clavicle, and are a common site for metastasis from breast carcinoma. From the sentinel nodes others of this supraclavicular group extend upward upon the jugular vein or anterior scalene muscle and also laterally along the subclavian

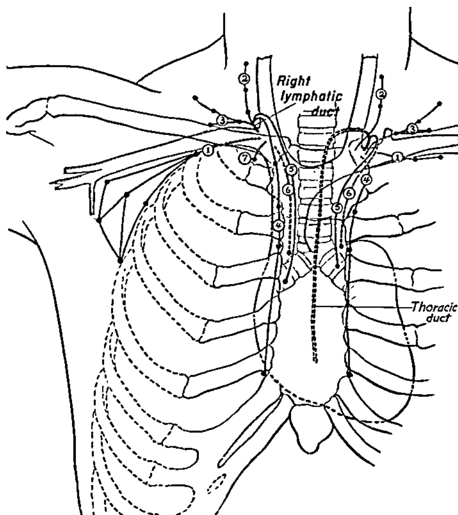


Fig. 255. THE GREAT LYMPHATIC TRUNKS AT THE BASE OF THE NECK EMPTYING INTO THE CONFLUENCE OF THE INTERNAL JUGULAR AND SUBCLAVIAN VEINS.

1, Subclavian efferent from the axilla. 2 and 3, Jugular from the internal jugular and supraclavicular nodes. 4, Internal mammary. 5, Anterior mediastinal. 6, From posterior mediastinal and laterotracheal group of nodes. 7, From posterior intercostal lymph node in the first interspace. (From Haagensen: Diseases of the Breast.)

Surgical Considerations

Clinical Examination of the Breast. This is an extremely important subject, because the breast is an external structure commonly the seat of cancer, and proper palpation and inspection will reveal small, usually early, tumors.

With the patient sitting up, careful observation easily shows the deformity due to large tumors and also the gross changes of retraction of the nipple and the orange peel or pigskin appearance. These are bad signs to find, since they mean late cancer, usually with axillary lymph node involvement, which, with the best of radical mastectomy and x-ray therapy, gives a five-year survival rate of only 30 per cent.

The whole aim is to detect early cancer. Barely perceptible dimpling of the skin and a slight retraction or tipping of the nipple are signs of early cancer. Even before these occur, careful palpation may reveal a tumor 1 cm. in diameter or less. This may be found with the patient sitting up, but the best position is to have the patient lying supine, with the arms raised over the head. The mobile breasts are then spread out in the thinnest possible layer over the chest wall, so that palpation of all areas with the flat of the hand will reveal any nodularity. The paramount decision to make is: Does this patient have a tumor? If she does, its immediate removal for pathologic examination is indicated. To observe further a tumor of the

Lymphatic Drainage from the Breast to the Opposite Axilla. The crossing of skin lymphatics from one breast area to the opposite side provides one explanation for metastasis reaching the opposite axilla in breast cancer. A second route for such contralateral spread is along the deep pectoral fascia lymphatics from one side to the other.

Lymphatic Drainage of the Muscles of the Chest Wall. These follow the general course of their blood supply. The lymphatics of the medial portion of the pectoralis major and minor muscles empty into the internal mammary lymph nodes, while the lateral portions drain to the axillary nodes. These receive also the lymphatic drainage from the fascia over the serratus anterior and from its superficial surface.

The external intercostal muscles are drained by collecting lymphatics following the intercostal vessels posteriorly to from one to three nodes in each interspace lying upon the inner aspect of the thoracic wall, close to the head of the ribs. These nodes also receive tributaries from the parietal pleura, the vertebrae and the spinal muscles, and provide a retrograde route whereby carcinomatous emboli from the breast *may reach the pleura or the vertebrae.* The normal efferent channel from these posterior intercostal nodes is to the thoracic duct.

The internal intercostal muscle lymphatics run anteriorly in the respective intercostal spaces to empty into the internal mammary lymph nodes. These nodes also receive lymphatics from the parietal pleura. Their ultimate efferent discharge is into the confluence of the internal jugular and subclavian at the base of the neck.

Haagensen stresses the major lesson from the review of breast lymphatics, that once emboli from carcinoma filter through the axillary lymph nodes and reach the subclavian trunk, their route into the venous circulation at the base of the neck is short and easy. Carcinoma in internal mammary nodes has a similar short path to the same veins and the same likelihood of general spread. Under such circumstances the most careful and radical surgical attack has little chance of curing carcinoma of the breast.

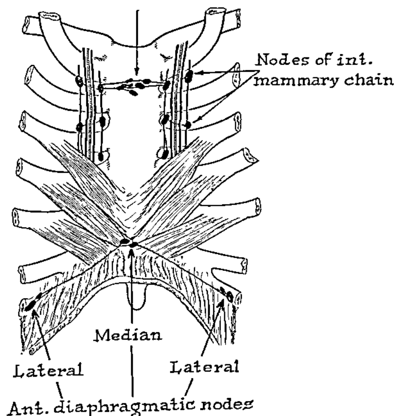


Fig. 254. RETROMANUBRIAL NODES ACCORDING TO ARÃO AND ABRÃO. (From Haagensen: Diseases of the Breast.)

mastitis, or abnormal involution. This lesion is tender and painful, particularly just before or during the menses. According to the rule that all tumors of the breast should be removed for pathologic diagnosis without delay, single cysts, because they cannot be differentiated from carcinoma, should be excised. Depending upon their site, a circumareolar, a radial, a curved incision following the skin lines or a thoracomammary incision can be used (Figs. 263, 264).

Papillomas are epithelial tumors arising from the walls of the breast ducts and are definitely precancerous lesions. Bleeding from the nipple is almost pathognomonic of the presence of a papilloma. These tumors may be intraductal, intracystic or diffuse. The last are called cyst-adenomas, and ramify throughout a varying portion of the duct system. The presence of a papilloma necessitates immediate excision because of the possibility of its malignant degeneration. Often it is possible to localize the area from which the bleeding arises by carefully palpating around the breast close to the nipple (Fig. 256) and noting where blood appears from a main duct opening. To remove the papilloma, a circumareolar incision is made and the duct containing the papilloma is excised (Fig. 257). If malignancy be found on microscopic study, a radical mastectomy is indicated.

Carcinoma of the Breast. About 4 per cent of all adult women suffer carcinoma of the breast, and for women this site is involved by cancer almost twice as frequently as any other

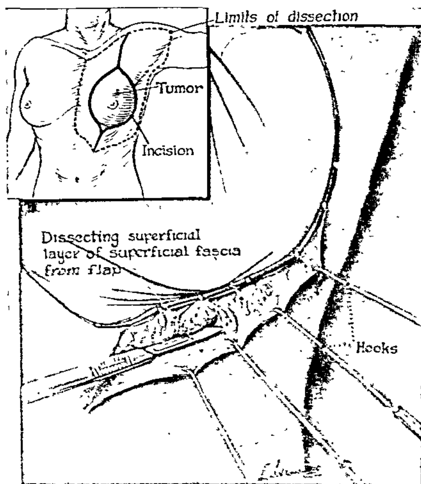


Fig. 258. RADICAL MASTECTOMY.

The incision for a carcinoma located near the center of the breast. As a rule it encompasses the skin over the whole of the protuberant mamma. For off-center lesions the circle is correspondingly shifted and goes at least 7 cm. beyond the edge of the palpable tumor. A skin graft is almost always needed to complete the closure. The dotted line shows the limit of the flaps, and their dissection begins at the lower end. The flaps are cut 3 to 4 mm. thick, taking only skin and the thin film of adipose tissue down to the level of the superficial fascia. (From Haagensen: Diseases of the Breast.)

breast is to watch for the signs of malignancy. Breast tumors should be found and removed before these are grossly apparent.

Whenever the breasts are examined, the axillae and supraclavicular areas should also be palpated.

INFLAMMATION OF THE BREAST. Breast infection is encountered with greatest frequency during the early stages of lactation when the gland tissue is highly vascular and functionally active. Abscesses occurring in the nonlactating breast follow infection of the glands of Montgomery and, therefore, are confined to the nipple zone.

Puerperal mastitis is the most frequent inflammatory lesion of the breast. The entrance of infection usually is at the nipple, and organisms rapidly invade the ducts and gland substance. This emphasizes the need for careful hygiene of the nipple. Infection spreads deeply from the superficial lesion, producing a suppurative lymphangitis (intramammary abscess). The abscess ramifies throughout the breast and gives rise to loculi traversed by fibrous septa. Inflammation, once started, has a tendency to spread from one lobule to another along the interglandular tissue, tunnelling the breast in various directions and leading to extensive destruction of the gland substance. Suppuration may take place outside the peripheral limits of the gland, either in the overlying tissue, *premammary abscess*, or in the loose areolar stratum upon which the gland lies, *retromammary abscess*. The latter variety more commonly arises from a deeper cause, such as pleural empyema or tuberculous osteitis of a rib, and tends to push the breast and major pectoral muscle anteriorly.

Incisions for the intramammary and premammary abscesses are made to radiate from the nipple to avoid injury to the lactiferous ducts. If a retromammary abscess results from forward spread from deeper structures, the breast may be turned upward by a long incision in the inframammary groove.

BENIGN TUMORS OF THE BREAST. Benign tumors of the breast are either solid or cystic. The solid tumors are encapsulated and freely movable. They consist either of relatively dense connective tissue, enclosing islands of fairly normal acini—the *periductal fibroma* or *adenofibroma;* or of loose myxomatous connective tissue, through which are scattered compressed, greatly distorted duct structures —the *intracanalicular fibroma* or *myxofibroma*. These solid tumors tend to extrude themselves from the gland and to become superficial to the bulk of mammary tissue. They are removed through a radial incision or a curved incision following the skin lines (Figs. 263, 264).

Mammary cysts result from the retention of duct secretion and may occur as single or multiple small, round tumors. They are found more frequently as one of the characteristic features of a diffuse process, *chronic cystic*

Fig. 256.

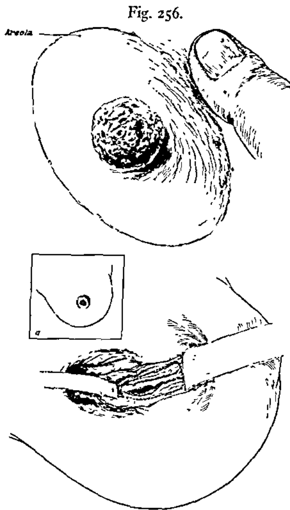


Fig. 257.

Fig. 256. LOCATING A MAIN DUCT PAPILLOMA OF THE BREAST BY CAREFULLY PALPATING ABOUT THE AREOLA.

Pressing on the duct involved expresses blood from the nipple opening. (From Snyder and Chaffin: A.M.A. Arch. Surg., 70: 680–85, 1955)

Fig. 257. EXCISION OF MAIN BREAST DUCT CONTAINING A PAPILLOMA.

Incision is around periphery of areola. Dilated duct is exposed and resected along dotted lines. (From Snyder and Chaffin: A.M.A. Arch Surg., 70: 680–85, 1955.)

frequently also carcinoma of the ducts within the mammary gland at some distance from the nipple.

Carcinomatous infiltration of the fibrous bands (Cooper's ligaments) between the skin, periglandular tissue and abundant lymph channels explains the frequent early fixation of the overlying skin, which, when marked, results in rough depressions looking like pigskin or the skin of an orange. Widespread skin involvement is hard and brawny, and when entirely unyielding is known as *cancer en cuirasse*. Similar deep extension may fix the carcinomatous mass to the chest wall (p. 271).

Lymphatic spread of breast cancer occurs rapidly, as evidenced by the fact that although half of all patients with breast cancer seek medical aid within six months after the first symptoms, at operation between 60 and 70 per cent are found to have axillary lymph node metastases. The disturbing significance is that those with such metastases have only a 40 to 50 per cent chance of five-year survival after radical mastectomy, whereas the reverse figures of 75 to 80 per cent five-year survival prevail if axillary nodes are not involved. Later in the course of the disease, as the lungs and blood vascular channels are invaded, widespread hematogenous dissemination occurs. The red marrow bones show this earliest, the most common sites being the ribs, vertebrae, skull, pelvis and upper ends of the femurs. Finally, a generalized carcinomatosis is present.

RADICAL MASTECTOMY FOR CARCINOMA. The purpose of this operation is to remove in one block the primary tumor in the breast with a wide margin of overlying skin and underlying pectoral fascia and muscles along with all axillary lymphatics. The surgical anatomical steps are presented briefly in Figures 258 to 261. It is realized that not all possible lymphatic spread is excised, and in endeavoring to im-

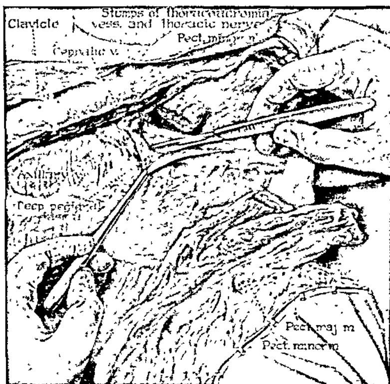


Fig. 260. RADICAL MASTECTOMY (CONTINUED).

The attachments of the pectoralis minor muscle have been severed from the ribs and the muscle allowed to fall laterally. This is aided by the dissection of the serratus fascia over the digitations of the serratus. The bulky mass of breast tissue and pectoral muscles has been allowed to fall away to the patient's side, giving good access to the axilla. This careful dissection is now begun by incising the deep pectoral fascia over the brachial plexus, parallel to and slightly cephalad to the axillary vein, and continues removing all fat and areolar tissue which contain the lymphatics anteriorly and below this structure. (From Haagensen: Diseases of the Breast.)



Fig. 259. RADICAL MASTECTOMY (CONTINUED).

The skin flaps have been widely dissected. The attachment of the pectoralis major has been severed at its insertion to the humerus and then dissected free from the deltoid along the cephalic vein. The pectoral branches of the thoraco-acromial artery and vein and the lateral anterior thoracic nerve are isolated, divided and tied. The attachment of the pectoralis major is divided 1 cm. below the clavicle and then severed from its broad origin from the sternum, the costal cartilages and ribs, and the fascia of the rectus and external oblique muscles, allowing the whole operative specimen to fall laterally to the patient's side. The perforating artery and veins should be carefully isolated and clamped before they are cut. The pectoralis minor muscle is then cut across 2 or 3 cm. from its insertion on the coracoid process and retracted caudad. (From Haagensen: Diseases of the Breast.)

location. To reduce the consequent mortality, women should carefully examine their breasts at least every three months. When any breast nodule is found, it should then not be merely observed; arrangements should be made promptly for its removal for pathologic examination.

Breast carcinoma has its origin either in the columnar epithelium of the ducts or in the glandular epithelium of the acini, the latter being more common. It begins as a small hard nodule which increases in size and infiltrates the surrounding tissue.

Conspicuous in the pathologic changes of many breast carcinomas is the contraction of the fibrous connective tissue or stroma which surrounds the site where the cancer cells are lodged, *scirrhous variety*. In this type, fibrosis is developed to the highest degree, with hardness, marked puckering and distortion of the surrounding tissues. In other types, which may grow more rapidly, the glandular element predominates, *medullary cancer*, and there is less tendency for contraction. Nipple retraction is caused by cicatricial changes in the tissues about the acini which are continuous superficially with those enveloping the large ducts traversing the nipple and opening on its summit.

Paget's disease of the nipple is a form of carcinoma originating in the ducts or epidermis of the nipple. It usually leads to induration, ulceration and eczematous exudation. There is

frequently also carcinoma of the ducts within the mammary gland at some distance from the nipple.

Carcinomatous infiltration of the fibrous bands (Cooper's ligaments) between the skin, periglandular tissue and abundant lymph channels explains the frequent early fixation of the overlying skin, which, when marked, results in rough depressions looking like pigskin or the skin of an orange. Widespread skin involvement is hard and brawny, and when entirely unyielding is known as *cancer en cuirasse*. Similar deep extension may fix the carcinomatous mass to the chest wall (p. 271).

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Radical Mastectomy for Carcinoma. The purpose of this operation is to remove in one block the primary tumor in the breast with a wide margin of overlying skin and underlying pectoral fascia and muscles along with all axillary lymphatics. The surgical anatomical steps are presented briefly in Figures 258 to 261. It is realized that not all possible lymphatic spread is excised, and in endeavoring to im-

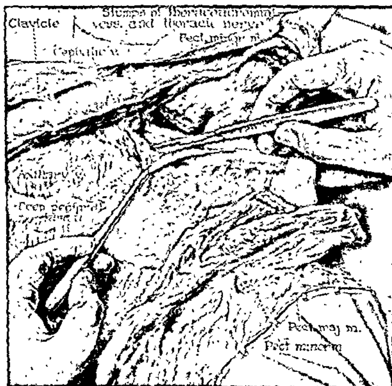


Fig. 260. RADICAL MASTECTOMY (CONTINUED).

The attachments of the pectoralis minor muscle have been severed from the ribs and the muscle allowed to fall laterally. This is aided by the dissection of the serratus fascia over the digitations of the serratus. The bulky mass of breast tissue and pectoral muscles has been allowed to fall away to the patient's side, giving good access to the axilla. This careful dissection is now begun by incising the deep pectoral fascia over the brachial plexus, parallel to and slightly cephalad to the axillary vein, and continues removing all fat and areolar tissue which contain the lymphatics anteriorly and below this structure. (From Haagensen: Diseases of the Breast.)

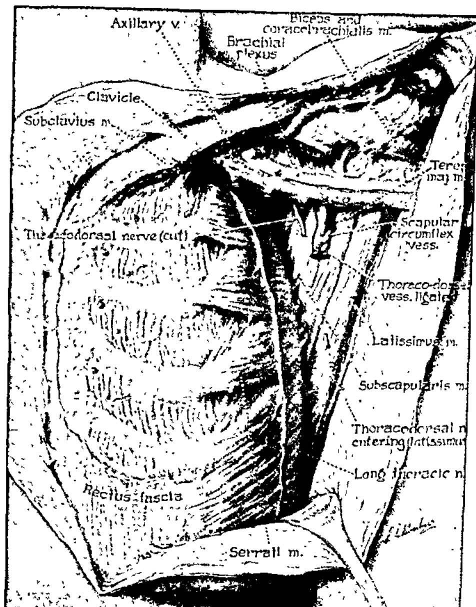


Fig. 261. RADICAL MASTECTOMY (COMPLETED).

The operative field at the completion of the dissection. The axillary vein and various muscles and fascia of the area have been laid bare. The intercostohumeral and thoracodorsal nerves have been sacrificed. The long thoracic nerve of Bell has been spared. The final step in the axillary dissection has been the excision of the specimen from along the groove between the chest wall and the latissimus dorsi muscle. Branches of the thoracodorsal vessels in this area have been isolated, clamped and ligated. (From Haagensen: Diseases of the Breast.)

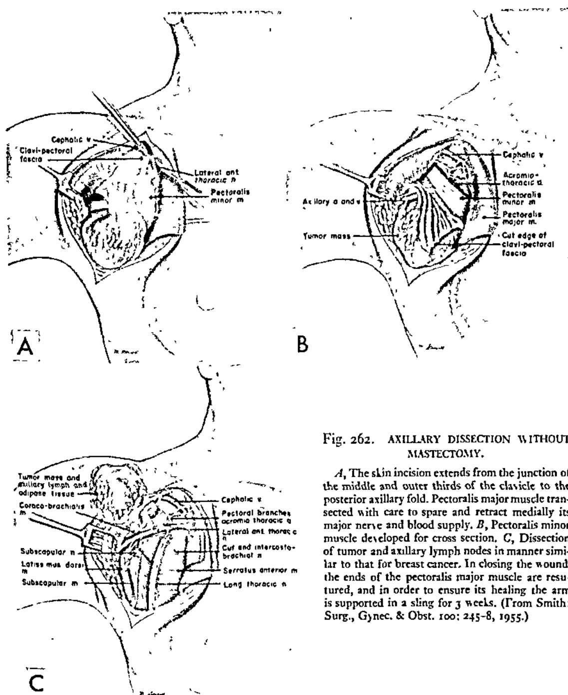


Fig. 262. AXILLARY DISSECTION WITHOUT MASTECTOMY.

A, The skin incision extends from the junction of the middle and outer thirds of the clavicle to the posterior axillary fold. Pectoralis major muscle transected with care to spare and retract medially its major nerve and blood supply. *B*, Pectoralis minor muscle developed for cross section. *C*, Dissection of tumor and axillary lymph nodes in manner similar to that for breast cancer. In closing the wound, the ends of the pectoralis major muscle are resutured, and in order to ensure its healing the arm is supported in a sling for 3 weeks. (From Smith: Surg., Gynec. & Obst. 100: 245-8, 1955.)

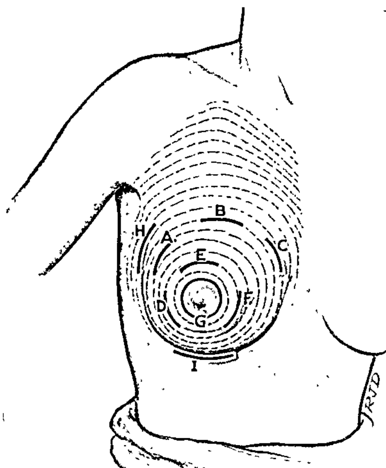


Fig. 263.

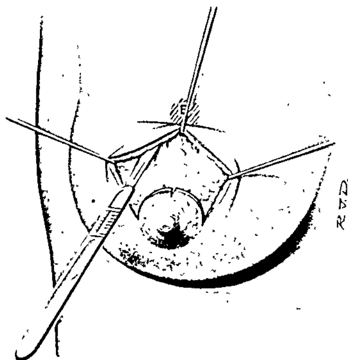


Fig. 264.

prove results some surgeons have extended their dissection to include the supraclavicular and internal mammary nodes.

Operation offers the only hope of curing carcinoma of the breast, x-ray therapy preoperatively or postoperatively, or both, possibly adding slightly to the survival rate.

Radical Axillary Dissection without Mastectomy. Occasionally this procedure is necessary in the surgical treatment of malignant lesions of the axilla, upper extremities and torso. The essential steps are pictured in Figure 262.

Incisions for Removal of Benign Tumors of the Breast. Every incision on the human body, no matter in what part, should be planned to allow proper carrying out of the necessary surgical procedure, and at the same time end with the best cosmetic result. The patient must live with this scar, and too often its appearance is nothing short of ugly.

Incisions radiating from the nipple cross the natural lines of the skin and ultimately widen. The circular incisions along Langer's lines offer just as much access to breast tissue, can be closed neatly, and ultimately become inconspicuous (Figs. 263, 264).

Diaphragm

Definition. The diaphragm is a dome-shaped musculomembranous structure separating the thoracic and abdominal cavities (Fig. 276). Its peripheral portion consists of muscle fibers which originate at the sternal, costal and vertebral margins of the thoracic outlet, and converge to an insertion in a central tendon. The diaphragm presents right and left vaults separated by a groove and depression upon which the heart and pericardium rest. The right vault mounts higher than the left; the highest point on each side is about 4 cm mesial to the mammary line.

Development of the Diaphragm. The diaphragm arises from five morphological elements—the central tendon, two ventrolateral and two dorsal parts. The *central tendon* is formed from the transverse septum, an embryonic layer of tissue separating the heart from the liver. The *ventrolateral portions* of the diaphragm arise from the ventrolongitudinal muscle layer of the body. The *dorsal portions* are derived from the paravertebral musculature. These segments fuse and leave a pleuroperitoneal foramen on each side posteriorly between each dorsal and corresponding ventrolateral part. These apertures close early in fetal life by a fusion of their margins. The openings through which the congenital and acquired diaphragmatic hernias occur are the pleuroperitoneal openings behind, two small passages in front, just behind the sternum, and the esophageal opening between the two dorsal divisions of the diaphragm. Of these openings, the esophageal presents the greatest weakness. The hiatuses for the aorta and vena cava are completely closed by the rigidity of the tendinous walls and the ability of the vessels to expand and completely fill their respective passageways.

Apart from respiratory function, and with reference to surgery, the esophageal hiatus is the most important region of the diaphragm. Despite this fact, the significance of variation in the musculature and fascial layers which form the boundary of the orifice is little appreciated. Any pathological process or surgical procedure which violates the integrity of the wall of the hiatus will interfere with the function of maintaining a unidirectional passage of food and fluid from the esophagus to the stom-

Fig. 263. CIRCULAR INCISIONS FOR REMOVAL OF BENIGN TUMORS OF THE BREAST.

The directions of Langer's lines are shown as a guide to the various incisions. If a tumor is situated near the periphery of the upper part of the breast, at points *A*, *B*, or *C*, the curved incisions follow Langer's lines and are placed medial to the tumor, as a precaution, should the lesion prove to be a carcinoma. It is advantageous to have the biopsy wound as near the center of the operative field as possible in planning the extent of a dissection for carcinoma. For the same reason the lateral paramammary incision *I* is avoided unless it is certain that the lesion is benign.

Tumors at *D*, *E* and *F* are best removed through a curved incision directly over the tumor or slightly medial to it. If the clinical features suggest that it is benign, the circumareolar incision is used (Fig. 264). (From Haagensen: Diseases of the Breast)

Fig. 264. TECHNIQUE FOR EXCISING A BENIGN TUMOR OF THE BREAST AT SOME DISTANCE FROM THE AREOLA.

There is some advantage in making a marking nick on the edge of the areola at the center of the intended incision. This makes it possible to resuture the incision accurately. The circumareolar incision is then made through the skin wound about half of the circumference of the areola. To approach the tumor at *E*, undercutting can then be done with little bleeding if the plane of the dissection is kept just above the superficial fascia. (From Haagensen: Diseases of the Breast).

ach (Carey and Hollinshead). This means that a knowledge of the variations in anatomical structure of the diaphragm is a matter of primary surgical importance. In a study of twenty-five adult specimens it was found that commonly, at the hiatus "collar," the musculature of the right crus splits into superficial (anterior) and deep (posterior) lamellae, the superficial lamella forming, alone, the right margin of the hiatus, while the deep lamella crosses to form, alone, the left margin of the hiatus. In two of the twenty-five specimens the left crus divided and contributed to both margins (these having, therefore, a truly bilateral origin); in two other specimens a small bundle from the left crus contributed to the right margin (Fig. 265).

Through the communications between the thorax and abdomen there may be reciprocal spread of infection, permitting pleuritis to follow peritonitis and peritonitis to follow pleuritis.

Relations. As a partition separating the thoracic and abdominal cavities the diaphragm has important relations to the contents of both.

The *thoracic surface* of the diaphragm forms the floor of the chest cavity, contacts the diaphragmatic pleura and pericardium, and is in relation to the cellular tissue of the anterior and posterior mediastina and right and left pulmonary pleurae. Through the intermedium of the costodiaphragmatic (phrenic) sinus the diaphragm has an important relation to the chest wall. The sinus contains a thin lappet of lung during inspiration, but is empty during expiration. Since the pleura does not reach the depth of the sinus, it is possible for a penetrating chest wound to enter the abdominal cavity without injury to either the lung or the pleura. Too low a thoracotomy for empyema may injure the diaphragm and, because of the proximity of the diaphragm to the ribs, may inhibit free drainage of the thoracic cavity. It is well established that, subsequent to subdiaphragmatic or hepatic abscess, the pleural surfaces of the sinus may become adherent, an anatomic consideration which permits incision and drainage of such an abscess without invasion of the general peritoneal cavity.

The *abdominal surface* of the diaphragm is covered by peritoneum, save where it is attached to the posterior and superior surfaces of the liver and at the level of the pancreas, duodenum and kidneys. It is related from right to left to the convex surface of the liver, the fundus of the stomach, the lateral surface of the spleen, and the left (splenic) flexure of the colon.

Phrenic Arteries and Veins. From a recent study of 425 laboratory specimens (850 body-halves) data have been secured on variations in the origin of phrenic arteries (Figs. 266, 267). Additionally, some observations were made in the corresponding veins and on the relations of both sets of vessels.

Usually a single large inferior phrenic artery occurs on each side of the body. These vessels usually arise from the aorta or from the celiac artery. The crura of the diaphragm enclose the aorta for a considerable distance, to form a muscular tunnel, the walls of which are only occasionally pierced by the vessels. In these rare instances an extension of a small slip of the diaphragmatic crus from the opposite side has crossed the midline inferior to the artery.

The inferior phrenic artery, in its ascent upon the anterior surface of the diaphragmatic crus, gives off branches to the adrenal gland, frequently to the kidney and renal capsule and to the crus of the corresponding side of the diaphragm. A sizable contribution is occasionally sent to the esophagus, where the latter passes through the diaphragm. The inferior phrenic artery usually bifurcates as it nears the dome of the diaphragm; the smaller posterior division courses laterally a short distance above the costal and lumbocostal origin of the diaphragm, where it anastomoses with the lower intercostal artery; the larger anterior division runs anterosuperiorly to the edge of the central tendon, where it anastomoses freely with the pericardicophrenic artery (the latter having descended to phrenic level along the lateral wall of the pericardial sac). Generally speaking, the veins behave in a similar way. On the right, the anastomosis occurs at the lateral posterior edge of the caval hiatus; on the left, near the lateral extremity of the central tendon.

In a large percentage of cases the inferior phrenic arteries arise in a small area at the apex of the aortic hiatus. In 91.9 per cent of cases (781 of 850 body-halves) the artery arises from the aorta and celiac axis, either independently or by a common trunk with the vessel of the opposite side. Of the two, the celiac origin is the more common, contributing 46.8 per cent (398 of 850), the aorta 45.1 per

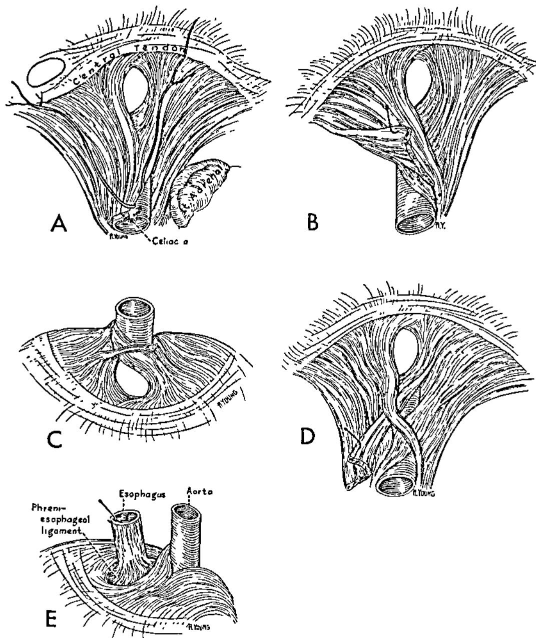


Fig. 265. FORMATION OF THE ESOPHAGEAL HIATUS; ARRANGEMENTS ENCOUNTERED IN 25 SPECIMENS, SHOWN SEMISCHEMATICALLY.

A and *C*, The usual mode of formation of the hiatus, pictured from below and above, respectively; in *C* the accessory bundle of fascicles is seen passing from the left crus to the right. *B*, The pattern found in 2 specimens; small bundles from the left crus form the right margin of the hiatus. *D*, An arrangement which occurred in 2 specimens; fibers from each crus pass to the opposite side, crossing in X-shaped fashion. *E*, The form of the ligamentous band which, as a derivative of the diaphragmatic fascia, ascends through the hiatus to surround the lower end of the thoracic part of the esophagus. (From Carey and Hollinshead. Surg., Gynec. & Obst., 100: 196–200, 1955.)

cent (383 of 850). Thereafter there is a sharp decline in frequency, all other sources combined accounting for only 8.1 per cent.

Among the infrequent types of origin, renal source stands first with 4.9 per cent (42 of 850).

Origin from the left gastric, which, as a branch of the celiac artery, turns superiorly, follows in the order of decreasing frequency; this type of origin makes up only 2.6 per cent of cases (twenty-two of 850). The hepatic artery, being removed even farther from the customary site of origin of the inferior phrenic,

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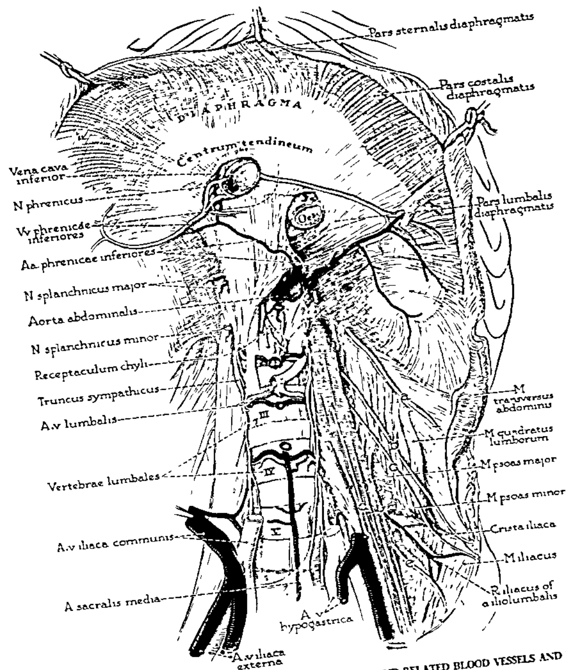


Fig. 267. RESPIRATORY DIAPHRAGM, LUMBAR MUSCLES AND RELATED BLOOD VESSELS AND NERVES.

Showing the portions of the diaphragm, the hiatuses and their contents, the lumbar musculature and vertebral column, together with the phrenic and lumbar blood vessels, and the nerves derived from the lumbar plexus in relation to the psoas major, quadratus lumborum and iliacus muscles.

The inferior vena cava, aorta and esophagus have been transected on the abdominal aspect of the diaphragm; the lumbar arteries have been cut where they arose from the aorta, the corresponding veins where they entered the inferior vena cava.

In this specimen the inferior phrenic arteries arose separately; the veins entered the inferior vena cava near the caval hiatus in the diaphragm. The rami of the phrenic nerve are shown as they ramify in the musculature.

Important is the demonstration that phrenic artery, vein and nerve course together, in familiar "pedicle" fashion, and through or at hiatuses in the diaphragm; these openings are the caval hiatus (on the body's right), and a less conspicuous fault in the musculature (on the left). The splanchnic nerves pierce the musculature of the diaphragmatic crura, which in this specimen are short. It is also worthy of note that the lumbar arteries do not leave each posterolateral aspect of the abdominal artery separately; rather, 4 pairs arise from a common stem; the fourth gives rise to the middle sacral artery and to small, laterally directed twigs, which represent the fifth lumbars. Key to lettering of nerves: *a*, twelfth thoracic; *b*, iliohypogastric; *c*, ilio-inguinal; *d*, lumbo-inguinal; *e*, lateral femoral cutaneous. (From Greig, Anson and Coleman: Quart. Bull., Northwestern Univ. M. School, 25: 345-50, 1951.)

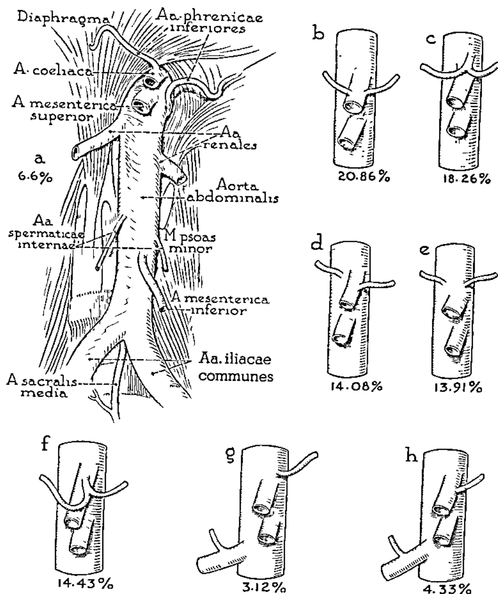


Fig. 266. VARIATIONS IN ORIGIN OF THE PHRENIC ARTERY; 8 TYPES, WITH PERCENTAGE OCCURRENCE OF EACH.

Together, these types represent 95.6 per cent of 850 body-halves studied. (From Greig, Anson and Coleman: Quart. Bull., Northwestern Univ. M. School, 25: 345–50, 1951.)

rarely served as the source vessel (0.5 per cent, or four in 850 body-halves). In two of the four instances the origin took place at the base of the hepatic artery just as the latter arose from the celiac, and hence only a short distance from the area of major supply. In the other two cases the inferior phrenic arose from the accessory hepatic arteries which followed a course considerably more cephalad than the usual channel (see footnotes to tabulation).

In but a single case (0.1 per cent of 850) an inferior phrenic artery arose from the internal spermatic artery—to complete the series in the order of decreasing frequency of occurrence. Since the distance from spermatic source to phrenic termination is considerable, occasional origin of the inferior phrenic artery from the splenic artery might reasonably be expected. However, not a single case of this type was encountered.

The venous drainage of the diaphragm is cared for chiefly through vessels which accompany the branches of the inferior phrenic arteries toward the neurovascular center of

lumbar spine (Fig. 268, *b*, *c*). Examination of the esophageal hiatus shows it to be a split in the muscle fibers of the right crus lightly reinforced by fibers from the left. In front the esophagus is supported by a sling of muscle fibers continuous on each side with the perpendicular fibers of the crus and decussating with one another to form a stoutly reinforced raphe, but behind there is less support, for it is here that the crus splits to form the hiatus. If the opening is enlarged, the pressure felt in front and at the sides may cause some atrophy of muscle fibers, but it can do little more because it is acting "across the grain." The pressure at the back, however, is felt "along the grain" and splits the fibers to increase the size of the opening. This will be referred to again, for it forms the key to the problem of surgical repair.

When the right crus of the diaphragm contracts, its action on the cardia is twofold: first, it compresses the walls of the esophagus from side to side, and, second, it pulls down and increases the angulation of the esophagus. This can easily be verified when the stomach is opened at operation, by inserting the index finger into the esophagus through the stomach. The angulation is increased both from before backward and from side to side. It will be noted that it is during inspiration, when the suction pressure in the chest would tend to draw the gastric contents into the esophagus, that the crus of the diaphragm contracts and obstructs this. An appreciation of these actions emphasizes the disregard for function in many of the methods of diaphragmatic repair advocated and illustrated in surgical monographs. A glance at the anatomy of the diaphragm shows that to stitch up the hiatus at the sides is to ruin the very muscle on which the function depends, and that to stitch it in front is merely to displace the esophagus backward. If the fibers of the crus are approximated to one another behind the esophagus, it needs only the lightest nonstrangulating sutures to keep them together (Fig. 269), but these operative details will be described later. Although no internal sphincter can be demonstrated, there is an intrinsic mechanism which contributes to continence, for when the esophagus and stomach are removed from the body, a greater pressure is necessary to drive fluid from the stomach to the esophagus than in the opposite direction. The oblique line of entry of the esophagus into the stomach is an important factor, and during

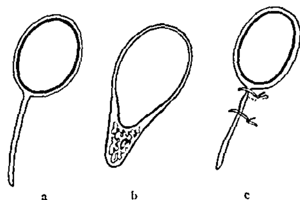


Fig. 269. FORMATION OF THE ESOPHAGEAL HIATUS.

a, Diagrammatic representation of the right esophageal hiatus. *b*, Further splitting of the crus when a hiatal hernia occurs. *c*, Restoration of the hiatus by light suturing of crural fibers behind the esophagus. (From Allison: Surg., Gynec. & Obst., 92: 419-31, 1951.)

life contraction of the circular muscle fibers of the esophagus and the oblique fibers of the stomach play their part. If the intrinsic mechanism is ineffective, the diaphragm alone may not be enough to ensure complete continence.

The position of the cardia in relation to the diaphragm is dependent partly on muscular action and partly on the ligamentous attachments (Fig. 270). The peritoneum on the surface of the stomach is reflected onto the under aspect of the diaphragm, and as it is closely applied to both these structures, its reflection forms something of a ligament. On its bare area of the stomach the retroperitoneal tissue is in continuity with that of the crural canal. The accumulation of fat in this may be the starting point of a weakness which predisposes to hernia. The deep fascia on the under surface of the diaphragm passes up through the hiatus to become continuous with the fascia propria of the esophagus, that part extending between the two being known as the phrenoesophageal ligament. It is separated from the diaphragmatic esophagus in the middle, and the peritoneal reflection below by the left gastric vessels, where they emerge from the retroperitoneal planes to enter the stomach and esophagus, the paracardiac glands and some cellular tissue which forms a bursa-like cushion to the diaphragmatic esophagus. The continuance of the diaphragmatic fascia into the fascia propria of the esophagus means that the pull of the diaphragm in inspiration is more evenly distributed over that organ, instead of being concentrated only at the cardia. The pull may be

each side. On the right one or more channels empty into the inferior vena cava where the caval vein pierces the diaphragm to enter the pericardial sac. On the left a vessel of considerable size, unaccompanied by an artery, is often found passing across the midline on the diaphragm to the inferior vena cava. When this vessel is absent or small, a proportional part of the venous return follows the main arterial stem back to the left crus, to empty into the left suprarenal vein after having received superior capsular tributaries.

LYMPHATICS AND NERVES. The pleural *lymphatics* anastomose through the diaphragm with the peritoneal lymphatics, possibly accounting for reciprocal infection of the pleural and peritoneal cavities. There seem to be no studies demonstrating conclusively which way lymph flows through these channels. From clinical observation a cephalad flow seems more likely. Considering the great many cases of pleural empyema, extension to below the diaphragm is rare. On the other hand, every surgeon has seen pleural empyema as a complication of a subphrenic abscess.

The motor and sensory *nerve supply* is derived mainly from the cervical plexus through the two phrenic nerves (C 3, 4, 5), which descend in the thorax on the lateral surface of the pericardium and the mediastinal pleura, in front of the lung roots, to be distributed to the superior surface of the diaphragm. They terminate in branches which penetrate the muscle. The diaphragm also is innervated by the diaphragmatic plexus of the sympathetic and sometimes by fibers from the lower thoracic nerves.

Surgical Considerations

DIAPHRAGMATIC HERNIA. In recent years the contributions of Allison* to the subject of reflux esophagitis, sliding esophageal hiatus hernia and the anatomy of repair have been outstanding. The deformity of sliding esophageal hiatus hernia is amenable to surgical repair, and if this can be done in such a way as to restore the physiologically active cardia, and if the patient is fit for operation, it should be advised for two main reasons: first, that the symptoms from reflux esophagitis are distressing to the patient and to those closely associated with him, and second, because persistent superficial inflammation is liable to be complicated by a chronic deep ulcer or reactive submucous fibrosis with stricture formation, when the surgical treatment may become unavoidable and much more formidable.

* Surg., Gynec. & Obst., 92: 419-31, 1951.

The function of the gastric cardia is to allow food to pass from the esophagus into the stomach and to prevent its return other than in exceptional circumstances. This carries with it the implication that it obstructs the reflux of digestive juices from the stomach into the esophagus. There has been much discussion about the presence or absence of a sphincter at the cardia. The following views are based on roentgenological, endoscopic and direct observations in health, disease and death in many patients.

The alimentary canal passes through two diaphragms, the thoracoabdominal and the pelvic. In each of these nature has adopted the same device for continence (Fig. 268). In each the canal is made to take a fairly abrupt bend, and at the bend is supported by an intrinsic and an extrinsic muscular mechanism. At the anorectal junction the internal sphincter is relatively well developed, but the main factor for continence is the puborectalis muscle, which forms a lasso around the pubic bone. At the esophagogastric junction there is no thickening of the circular muscle fibers of the esophagus to form a sphincter, but the canal takes a bend forward and to the left, and this bend is lassoed and maintained by the right crus of the diaphragm which stitches it down to the

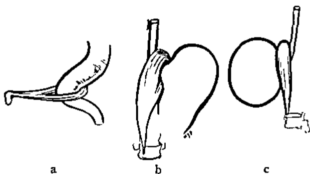


Fig. 268. SIMILAR DEVICES FOR CONTINENCE OF THE ALIMENTARY CANAL AT THE ANORECTAL JUNCTION AND THE ESOPHAGOGASTRIC JUNCTION.

These consist of a fairly abrupt bend supported by an intrinsic and extrinsic muscular mechanism. *a*, The puborectalis sling around the anorectal junction. *b*, Anterior view of the right crus of the diaphragm forming a sling for the esophagogastric junction. *c*, The sling of the right crus as seen from the side. (From Allison: Surg., Gynec. & Obst., 92: 419-31, 1951.)

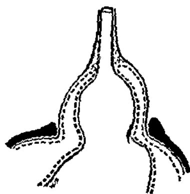


Fig. 272. SLIDING HIATAL HERNIA.

Note the stretching of the peritoneal reflection and the phrenoesophageal ligament. Acute angle between esophagus and stomach disappears, and the cardia *slides up* into the mediastinum. Regurgitation with esophagitis, ulceration and heartburn is common in these patients. The esophagus appears short, but at operation can usually be pulled down into its normal position. With long-standing and severe esophagitis, chronic ulceration, submucous fibrosis and stricture formation may occur with a *freezing* of the esophagus into a short position no longer reducible. (From Allison: Surg., Gynec. & Obst., 92: 419-31, 1951.)

stomach, and the transverse colon pulled into the sac by the drag of the gastrocolic omentum. But in spite of all this displacement the esophagus still enters the stomach at an acute angle; furthermore the dilated stomach, lying between the pericardium and spine, compresses the esophagus from before backward, so that regurgitation of gastric contents into the esophagus does not occur. The patients may complain of fullness after meals, wind around the heart, palpitation, shortness of breath, and may suffer peptic ulcers of the stomach which may bleed or perforate; there may be gross secondary anemia from constant small losses of blood, or an emergency may occur from volvulus of the stomach, but these patients do not have esophagitis with ulceration of the esophagus and heartburn.

If, however, no hernial sac exists, but a general weakening of the muscles and ligaments at the cardia occurs, perhaps associated with protrusion of retroperitoneal fat into the crural canal, what amounts to a direct hernia results (Fig. 272). In this the acute angle between the esophagus and stomach disappears and the cardia *slides* up into the mediastinum, taking the elongated phrenoesophageal ligament and peritoneal reflection with it. The stomach hangs like a bell from the esophagus; the esophagus, a highly elastic organ, recoils so that it appears shorter, but the whole may be pulled back into its normal position by slight traction on the stomach at operation, showing that the esophagus is relaxed, but not actually short. Patients presenting this picture regurgitate digestive juices into the gullet, and may have superficial esophagitis and complain of heartburn, all of which can be cured by a simple reduction of the hernia. Without surgical treatment the esophagitis may progress to chronic ulceration, submucous fibrosis, and

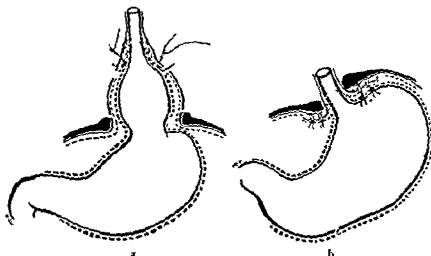


Fig. 273. REDUCTION AND REPAIR OF SLIDING HIATAL HERNIA IN 2 STEPS.

a, Division of peritoneal reflection and phrenoesophageal ligament close to the cardia. *b*, Suture of cut edges of peritoneum and phrenoesophageal ligament to the under aspect of the diaphragm. (From Allison: Surg., Gynec. & Obst., 92: 419-31, 1951.)

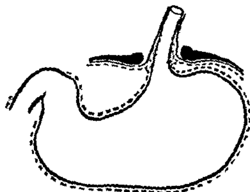


Fig. 270. THE NORMAL FASCIAL AND PERITONEAL REFLECTIONS AT THE DIAPHRAGMATIC HIATUS.

The peritoneum of the surface of the stomach is reflected onto the under aspect of the diaphragm. The fascia on the deep surface of the diaphragm is reflected onto the esophagus as the phrenoesophageal ligament and fascia propria. Vessels and lymphatics lie between this and the peritoneal reflection. (From Allison: Surg., Gynec. & Obst., 92: 419-31, 1951.)

likened to that of a parachute on an airman's harness compared with the more abrupt effect if the parachute were attached by a collar to the man's neck. The necessity for this is realized if the diaphragm is carefully dissected, for it is thereby demonstrated that while the decussation of the crural fibers in front of the esophagus is soft and muscular on the abdominal side, on its upper surface it is reinforced by tendinous fibers which form a firm edge against the esophagus.

Hernias through the hiatus are of two main varieties, the paraesophageal or rolling, and the sliding. Since these two give rise to different symptoms and have a different prognosis, it is worth considering their exact anatomy. It seems likely in some people that a protrusion of the peritoneal sac may remain at the hiatus, in much the same way as it may remain at the inguinal canal. As, during development, the stomach prolapses into the peritoneum from behind, leaving the cardia bare on its posterior surface, it is inevitable that if a protrusion of peritoneum is left in the mediastinum, it must occur in front of the esophagus (Fig. 271, *a*), as an inguinal sac for similar reasons always lies in front of the cord. This "preformed" hernial sac may remain empty during the whole of a patient's life, or at any age a part of the anterior surface of the stomach may project into it. So long as the ligaments of the cardia remain strong, the hernial sac can fill only by the rolling up of the anterior wall of the stomach (Fig. 271, *b*), and so it happens that in extreme degrees the stomach is found upside down in the mediastinum within a peritoneal sac, the great omentum hanging down from what is now the upper border of the

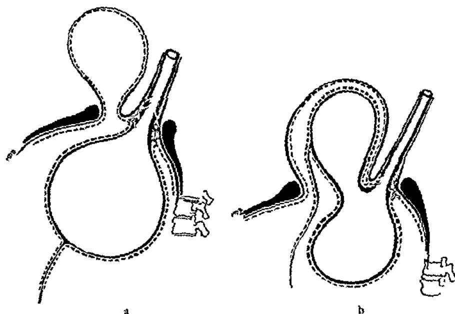


Fig. 271. PARAESOPHAGEAL HERNIA.

a, Preformed peritoneal sac covered by fascia lying in front of the esophagus. *b*, Anterior wall of the stomach rolled up into the sac to form a paraesophageal hernia. Note that the esophagus still enters the stomach at an acute angle, so that regurgitation of gastric contents does not occur. These patients do not suffer esophagitis with ulceration and heartburn. (From Allison: Surg., Gynec. & Obst., 92: 419-31, 1951.)

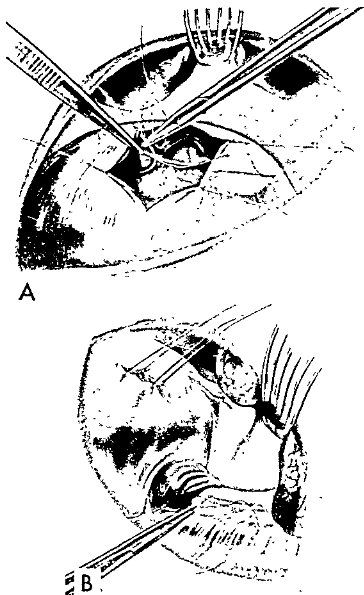


Fig. 275. ESSENTIALS IN REPAIR OF SLIDING ESOPHAGEAL HIATUS HERNIA (CONTINUED).

A, View through the diaphragmatic incision to show the cut edges of the phrenoesophageal ligament and peritoneum being sutured to the abdominal aspect of the diaphragm. *B*, Exposed and cleaned right crural muscle bundle approximated lightly by one or 2 silk sutures. The esophagus should be comfortably lodged in the newly formed crural canal. The fascia on the thoracic side of the crura may be sutured firmly from side to side, and as this layer is very thin, the cut edge of the pleura may be incorporated in these stitches close to the esophagus. The diaphragmatic incision is then closed with interrupted silk sutures. The chest wound is closed in layers. (From Allison: Surg., Gynec. & Obst., 92: 419-31, 1951.)

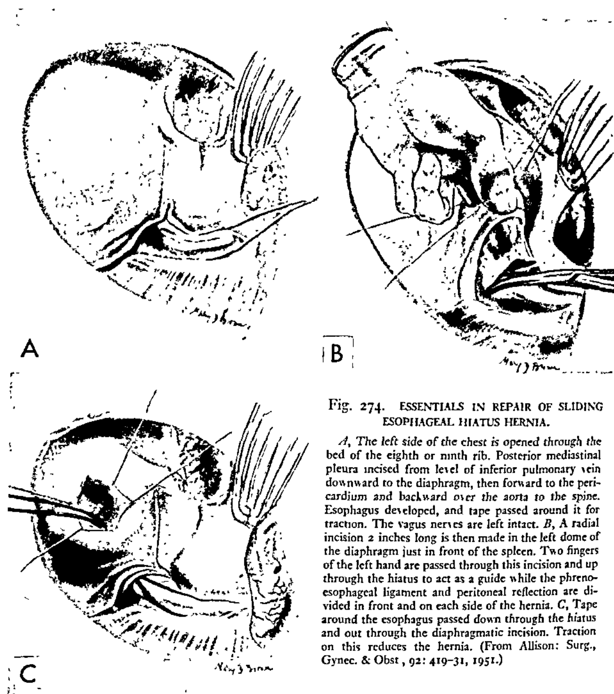


Fig. 274. ESSENTIALS IN REPAIR OF SLIDING ESOPHAGEAL HIATUS HERNIA.

A, The left side of the chest is opened through the bed of the eighth or ninth rib. Posterior mediastinal pleura incised from level of inferior pulmonary vein downward to the diaphragm, then forward to the pericardium and backward over the aorta to the spine. Esophagus developed, and tape passed around it for traction. The vagus nerves are left intact. *B*, A radial incision 2 inches long is then made in the left dome of the diaphragm just in front of the spleen. Two fingers of the left hand are passed through this incision and up through the hiatus to act as a guide while the phreno-esophageal ligament and peritoneal reflection are divided in front and on each side of the hernia. *C*, Tape around the esophagus passed down through the hiatus and out through the diaphragmatic incision. Traction on this reduces the hernia. (From Allison: Surg., Gynec. & Obst., 92: 419–31, 1951.)

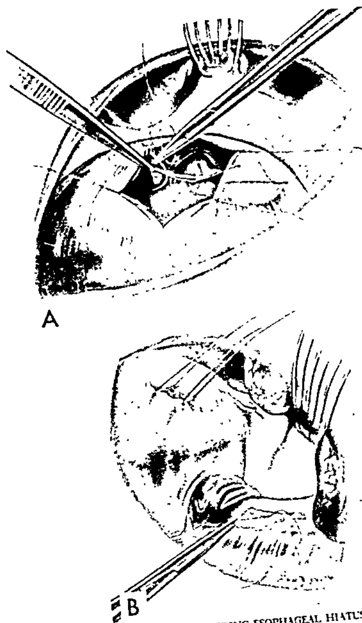


Fig. 275. ESSENTIALS IN REPAIR OF SLIDING ESOPHAGEAL HIATUS HERNIA (CONTINUED).

A, View through the diaphragmatic incision to show the cut edges of the phrenoesophageal ligament and peritoneum being sutured to the abdominal aspect of the diaphragm. *B*, Exposed and cleaned right crural muscle bundle approximated lightly by one or 2 silk sutures. The esophagus should be comfortably lodged in the newly formed crural canal. The fascia on the thoracic side of the crura may be sutured firmly from side to side, and as this layer is very thin, the cut edge of the pleura may be incorporated in these stitches close to the esophagus. The diaphragmatic incision is then closed with interrupted silk sutures. The chest wound is closed in layers. (From Allison: Surg., Gynec. & Obst., 92: 419–31, 1951.)

Foramen venae cavae
Pars lumbalis diaphragmatis
Arcus lumbocostalis medialis
Arcus lumbocostalis lateralis
M. psoas minor
M. quadratus lumborum
M. psoas major
M. iliacus
Pars sternalis diaphragmatis
Pars costalis diaphragmatis
Esophagus
Centrum tendineum
Hiatus aorticus
Aorta abdominalis
Crus laterale
Crus intermedium
Crus mediale
M. transversus abdominis
M. quadratus lumborum
Crista iliaca
M. iliacus
1
2

Fig. 276. DIAPHRAGM VIEWED ANTERO-INFERIORLY.

The thorax is bent backward; the fascia lumbodorsalis is removed to show the muscles of the posterior abdominal wall; the psoas muscles are removed on the left to show the M. quadratus lumborum and M. iliacus.

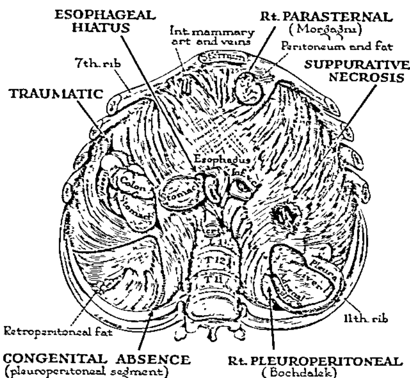


Fig. 277. TYPES OF DIAPHRAGMATIC HERNIA, SHOWN IN A VIEW OF THE SUPERIOR SURFACE OF THE RESPIRATORY DIAPHRAGM.

Hernias may owe their inception to trauma, to suppurative erosion or to a developmental defect. In the last-named category belong the following varieties: those due to segmental failure in development of the posterior pleuroperitoneal compartment (a defect which varies in size from production of a small cleft to a condition of hemidiaphragm); herniation caused by pathological anatomy at the esophageal hiatus; hernia at the small parasternal aperture, between the sternal and costal attachments of the diaphragm, which transmits the superior epigastric artery and vein. (From McVay, in Davis: Christopher's Textbook of Surgery.)

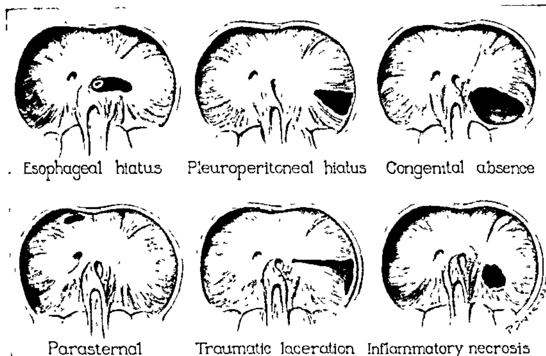


Fig. 278. SITUATIONS OF CONGENITAL STRUCTURAL DEFECTS AND TRAUMATIC LACERATIONS OF THE DIAPHRAGM WHICH CAUSE THE MORE COMMON TYPES OF DIAPHRAGMATIC HERNIA.

Occurrence in a total of 430 cases: esophageal hiatus (and short esophagus type), 343; congenital pleuroperitoneal hiatus, 9; congenital absence of posterior fourth left diaphragm, 12; congenital defect at the foramen of Morgagni, 8; traumatic lacerations of left diaphragm, 57; of right diaphragm, one. (From Harrington: Surg., Gynec. & Obst., 86: 735-55, 1948.)

stricture formation. In this event fibrosis renders the esophagus inelastic and "freezes" it in the retracted position so that the hernia is no longer reducible. The problem then becomes one of resection of a fibrous and ulcerated esophagus with all the technical hazards that that implies.

It needs stressing that with a sliding hernia it is the irritation of the esophagus which causes the symptoms, and that ulceration, when it occurs, is dependent upon the anatomical derangement of the cardia. The problem is, therefore, different from peptic ulcer of the stomach, and the aim of surgery must be to restore those factors to normal which have already been described as being responsible for the protection of the esophagus. This is achieved by two main steps: first, by division of the extended phrenoesophageal ligament and peritoneal reflection close to the cardia, and the resuturing of these to the under aspect of the diaphragm (Fig. 273), and second, by application of vertical fibers of the crus to one another behind the esophagus, and their retention thus by such light suturing as will enable them to continue to act as muscle (Fig. 269).

Essentials of the technique in carrying out these repairs are shown in Figures 274 and 275.

Although hernias occur most frequently at the esophageal hiatus (Fig. 276), other sites and conditions are important (Figs. 277, 278).

CHAPTER 13

Thoracic Cavity and Its Contents

Unlike the abdomen, which contains but a single sac, the chest cavity presents three complete serous sacs. These are the two pleurae and the pericardium. The chest affords space for many important structures: the lungs and heart, and those structures whose function extends beyond the thorax, either to the abdomen or to the neck. The more important of the latter are the major portion of the great vessels from the heart and lungs, the esophagus, the trachea, the vagus and phrenic nerves, the thoracic duct and the sympathetic nerve trunks. For descriptive purposes, the thoracic cavity and its contents are considered in three sections: the pleurae and pleurothoracic topography, the lungs and pulmonothoracic topography, and the mediastinum.

Pleurae and Pleurothoracic Topography

The pleurae are two serous membranes which form independent closed sacs. Into each sac at its mesial aspect is invaginated the respective lung. Thus two leaves or layers are present: one, applied over and adherent to the walls of the thorax, the parietal layer; and the other, intimately applied over the surface of the invaginated lung, the visceral or pulmonary layer. These layers are designed to effect excursion of the lungs over the walls of the thorax with a minimum of friction. Between the layers is the pleural cavity, normally a potential space containing a minute amount of serous fluid, but, under certain pathologic conditions, constituting a true cavity.

Pulmonary or Visceral Pleura. The thin pulmonary pleura is bound down firmly to the lung surface, and dips into the interlobar fissures, separating the lobes. It cannot be detached without laceration of the lung substance. It is continuous at the root of the lung with the pleura over the mediastinum.

Divisions of the Parietal Pleura. The divisions of the parietal pleura are important from topographic and surgical points of view (Figs. 279, 280). The costal portion is in contact with the ribs, intercostal spaces and endothoracic fascia, and the diaphragmatic portion with the superior surface of the diaphragm. The mediastinal division covers the lateral wall of the mediastinum.

The *costal pleura* is resistant, but, because of its loose attachment to the endothoracic fascia, is separated easily from the chest wall. It continues anteriorly into the mediastinal pleura and forms with it a vertical sinus or cul-de-sac along the costomediastinal line of pleural reflection, known as the anterior costomediastinal sinus. In a similar fashion the posterior costomediastinal (vertebromediastinal) sinus is formed. The costal pleura dips inferiorly into the groove formed between the costal wall and the diaphragm to form, along the costodiaphragmatic line of pleural reflection, the inferior or costodiaphragmatic sinus.

The *diaphragmatic pleura* spreads over the diaphragm and is adherent to the muscle, carpeting the area not covered by the diaphragmatic pericardium. It does not extend to the line of attachment of the diaphragm to the chest wall, but is separated from it by an interval containing fatty areolar connective tissue.

The *mediastinal pleura* is in loose contact with the structures against which it rests. In the upper part of the cavity on each side, it extends without interruption from the sternum to the spine, but below is reflected from the pericardium over the root of the lung and becomes continuous with the pulmonary pleura.

Lines of Pleural Reflection, and the Pleural Reserve Sinuses. At certain levels the parietal pleura is folded upon itself as it is reflected from one wall of the chest cavity to the other. Two of these reflections, the anterior, or

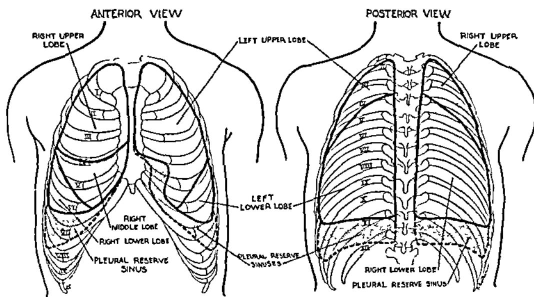


Fig. 279. BORDERS OF THE PLEURAE AND LUNGS IN ANTERIOR AND POSTERIOR VIEWS.

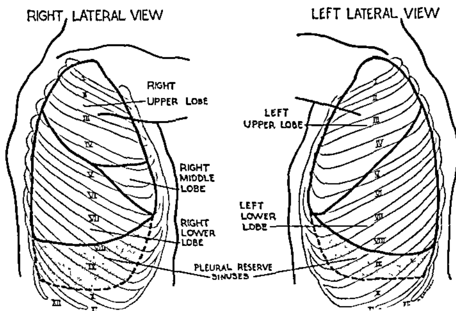


Fig. 280. BORDERS OF THE PLEURAE AND LUNGS IN LATERAL VIEWS.

costomediastinal, and the lower, or costodiaphragmatic, have a high degree of practical interest. Within these reflections are the pleural reserve sinuses, the costomediastinal and costodiaphragmatic spaces, which are invaded by the lung margins only in deep inspiration. During expiration the pleural leaves of the recesses are approximated; during inspiration they allow the salient lung margins to expand to their capacity (Figs. 279, 280).

Knowledge of the exact levels of the *costomediastinal sinuses* permits transthoracic exploration of the pericardium, heart and esophagus without opening the pleural sacs and incurring the complication of pneumothorax.

The pleura reaches the vertebral column at the level of the twelfth thoracic spine, about 1 cm. inferior to the head of the twelfth rib. The high level of the *inferior* or *costodiaphragmatic level of pleural reflection* permits additional exposure through the inferior margin of the thoracic cage in difficult operations on the stomach and liver. The fatty areolar interval between the pleural reflection and the costal

attachments of the diaphragm affords an extrapleural transthoracic approach to the diaphragm and to the underlying subdiaphragmatic space.

The pleural reflections are subject to some variation. Behind the sternum, one or the other costomediastinal reflection may advance farther anteriorly than usual, or fall short of its normal limit and reach perhaps only to the anterior extremities of the costal cartilages. The practical significance of the variation is evident when considered with reference to the precordial region. With normal pleural reflections the pericardium can be reached through the anterior extremities of the fifth and sixth interspaces without opening the pleura. If the left line of pleural reflection exceeds the normal limits and advances medially over the precordial area, it is injured in pericardial tap. There always is uncertainty as to how much of the pericardium is covered by pleura.

The *pleural dome* or *cervical pleura* is projected upward and forward into the neck. It is indicated on the surface by a curved line with an upward convexity, drawn from the center of the sternoclavicular joint to the junction of the sternal and middle thirds of the clavicle. The apices of the lung during both inspiration and expiration fill the domes completely. The anterior and middle scalene muscles lie upon the lateral surface of the cervical pleura before they attach to the upper surface of the first rib. *The subclavian artery lies in a groove on the medial and ventral aspect of the pleural dome.* The internal mammary vessels, the beginning of the vertebral and intercostal arteries, the inferior ganglion of the cervical chain, and the lower trunk of the brachial plexus also rest upon the cervical pleura.

Surgical Considerations

PRESSURE CONDITIONS WITHIN THE PLEURAL CAVITIES. The pressure relations within the pleural cavities are of the utmost practical significance. The lungs normally fill the pleural cavities completely except for the pleural reserve sinuses (p. 293), these being, therefore, only potential spaces. The pleural surfaces are kept in contact by the negative intrapleural pressure and the cohesive property of the opposed serous membranes. The lungs, owing to their elasticity, tend to contract, but are prevented from doing so by the counteracting force of the negative intrapleural pressure. While the pleural cavities remain closed, the lung is unable to recede from the chest wall unless there is an alteration in the intrapleural pressure produced by fluid or air. As long as the parietal pleura is intact, the visceral layer lies in contact with it; but if the parietal pleura is opened, air enters, and the lung, greatly diminished in volume, falls away from the chest wall. The unopposed elasticity of the lung allows the viscus to collapse actively.

Collapse of the lung would not be of great moment were it not for the fact that the mediastinum is a flexible composite and is capable of shifting rapidly (mediastinal flutter) with each respiration. Under altered pressure conditions, respiratory and circulatory embarrassment may be incompatible with life. This incompatibility is explained partly by the sudden pressure alterations, displacement of the heart and great vessels, and the diminished vital capacity of the good lung. Inability to cope with these alarming results for many years retarded the development of thoracic surgery. Clearer conceptions of respiratory mechanics and methods devised to maintain normal respiratory movements under positive pressure have furnished a marked impetus to surgery of the chest.

PNEUMOTHORAX. Pneumothorax is the presence of air in the pleural cavity. Air may enter through a perforation in the lung, parietal pleura or esophagus. Pneumothorax complicating pulmonary tuberculosis results from rupture of a tuberculous cavity in the periphery of the lung. This complication would be far more common were it not for the attendant adhesive pleuritis which often involves both layers of pleura and prevents air from entering between them. Injuries of the chest may produce sucking wounds with resulting progressively increasing pressure within the pleural cavity.

The production of pneumothorax in chest operations formerly caused serious symptoms and even death. Appreciation of the knowledge that lung collapse is much decreased when the pleural layers are adherent and the mediastinum is fixed by inflammatory deposits, together with the experience that mediastinal flutter may be stopped by grasping and holding the lung or limiting or closing the thoracic opening, has led to the adequate handling of these cases. Pneumothorax is induced artificially to put the lung at rest, to obliterate cavities within it, and to stop bleeding from the

lung in hemothorax from lung injury. It is also of value in the differential diagnosis of intrathoracic tumors, whether in the lung, pleura or mediastinum.

FIBRINOUS PLEURISY (PLEURITIS). The normal pleural surfaces are smooth and glistening, and are moistened by serous fluid which facilitates the movements between the opposed layers. When the pleura is inflamed, its surfaces are roughened from the deposition of fibrin, and a characteristic *friction sound* or *rub* may be heard on auscultation over the affected area. This is produced by the rubbing of the roughened surfaces against each other. The rub may be detected by applying the hand flat against the chest and, when perceived in this way, is called *friction fremitus*. Pleural inflammation may give rise to adhesions between the visceral and parietal layers.

The referred pain of fibrinous pleurisy varies according to the position of the pleura involved. The visceral pleura, which invests the lung, is not sensitive to painful stimuli; whereas the parietal pleura is supplied with sensory nerves through which stimuli are perceived acutely. Irritation of the costal pleura causes pain at the point of stimulation, but irritation of the diaphragmatic pleura causes pain referred to the neck, shoulder, scapula, back or abdomen. Spasm of the muscles overlying a lung lesion (Pottenger's sign) may be of definite diagnostic value.

Irritation of the central portion of the diaphragm in *diaphragmatic pleurisy* causes neck, and sometimes shoulder, pain on the corresponding side. The pain is referred over the trapezius muscle and occasionally above the clavicle, where it is transmitted by the phrenic nerve. Irritation of the periphery of the diaphragm refers pain to the lower dorsal and lumbar regions and to the flank and abdomen. There frequently is associated hyperesthesia of the skin areas innervated by the seventh to tenth spinal nerves. These symptoms are caused by the combined thoracic, abdominal and diaphragmatic distribution of the lower intercostal nerves. Often the costal and diaphragmatic pleurae are inflamed at the same time.

The most severe pleural pain occurs in pleurisy secondary to basal pneumonia. In many instances the pain is abdominal and, on that account, frequently is misinterpreted as arising from an acute abdominal lesion, such as acute appendicitis, cholecystitis or subdiaphragmatic infection. Differentiation between the conditions is aided by the knowledge that the common neck pain of diaphragmatic pleurisy does not occur in acute abdominal disease. Furthermore, the frequent relief of pain on deep pressure over the abdomen in pleurisy is in contrast to the accentuation of pain upon the same procedure in appendicitis and cholecystitis. The pleuritic pain is increased on deep inspiration. An acute inflammatory lesion just beneath the diaphragm offers the greatest difficulty in differential diagnosis, since the irritation of the peritoneal surface of the diaphragm refers pain after the same manner as does irritation of the pleural surface.

HYDROTHORAX, AND PLEURISY WITH EFFUSION. *Hydrothorax* is noninflammatory and is produced by a transudate, commonly a part of a general dropsy, which results from cardiac decompensation. It is, as a rule, unilateral, on the right side. Unilateral hydrothorax also may occur in profound anemia or in compression of the venous trunks by an aneurysm of the aorta, or tumor of the lung or of the mediastinal structures. In renal disease the hydrothorax almost always is bilateral. The symptoms produced by the fluid are the result of compression of the lung and displacement of the heart, and are chiefly dyspnea, cyanosis and acceleration of the pulse.

The commonest cause of *pleurisy with effusion* is tuberculosis. The serous exudate may be the second stage of a dry pleurisy, but often the exudate is present from the onset. When effusion occurs, the inflamed pleural surfaces are separated, and the pain diminishes or disappears. At first there is dyspnea from pain; later, unless the effusion has occurred slowly, there is dyspnea from pressure of fluid upon the lung and mediastinal displacement. In severe cases, orthopnea and cyanosis are present. The fluid has the usual characteristics of an inflammatory exudate. In hydrothorax and in pleurisy with effusion the mediastinal structures are displaced toward the unaffected side, and the diaphragm is depressed.

EMPYEMA. Empyema is a pleuritis with a purulent exudate, and usually is secondary to a pulmonary lesion (Fig. 282). Its presence is determined by clinical signs, roentgenologic examination, and aspiration.

Early empyema may occupy the entire pleural cavity (total), compressing the lung,

attachments of the diaphragm affords an extrapleural transthoracic approach to the diaphragm and to the underlying subdiaphragmatic space.

The pleural reflections are subject to some variation. Behind the sternum, one or the other costomediastinal reflection may advance farther anteriorly than usual, or fall short of its normal limit and reach perhaps only to the anterior extremities of the costal cartilages. The practical significance of the variation is evident when considered with reference to the precordial region. With normal pleural reflections the pericardium can be reached through the anterior extremities of the fifth and sixth interspaces without opening the pleura. If the left line of pleural reflection exceeds the normal limits and advances medially over the precordial area, it is injured in pericardial tap. There always is uncertainty as to how much of the pericardium is covered by pleura.

The *pleural dome* or *cervical pleura* is projected upward and forward into the neck. It is indicated on the surface by a curved line with an upward convexity, drawn from the center of the sternoclavicular joint to the junction of the sternal and middle thirds of the clavicle. The apices of the lung during both inspiration and expiration fill the domes completely. The anterior and middle scalene muscles lie upon the lateral surface of the cervical pleura before they attach to the upper surface of the first rib. The subclavian artery lies in a groove on the medial and ventral aspect of the pleural dome. The internal mammary vessels, the beginning of the vertebral and intercostal arteries, the inferior ganglion of the cervical chain, and the lower trunk of the brachial plexus also rest upon the cervical pleura.

Surgical Considerations

Pressure Conditions within the Pleural Cavities. The pressure relations within the pleural cavities are of the utmost practical significance. The lungs normally fill the pleural cavities completely except for the pleural reserve sinuses (p. 293), these being, therefore, only potential spaces. The pleural surfaces are kept in contact by the negative intrapleural pressure and the cohesive property of the opposed serous membranes. The lungs, owing to their elasticity, tend to contract, but are prevented from doing so by the counteracting force of the negative intrapleural pressure. While the pleural cavities remain closed, the lung is unable to recede from the chest wall unless there is an alteration in the intrapleural pressure produced by fluid or air. As long as the parietal pleura is intact, the visceral layer lies in contact with it; but if the parietal pleura is opened, air enters, and the lung, greatly diminished in volume, falls away from the chest wall. The unopposed elasticity of the lung allows the viscus to collapse actively.

Collapse of the lung would not be of great moment were it not for the fact that the mediastinum is a flexible composite and is capable of shifting rapidly (mediastinal flutter) with each respiration. Under altered pressure conditions, respiratory and circulatory embarrassment may be incompatible with life. This incompatibility is explained partly by the sudden pressure alterations, displacement of the heart and great vessels, and the diminished vital capacity of the good lung. Inability to cope with these alarming results for many years retarded the development of thoracic surgery. Clearer conceptions of respiratory mechanics and methods devised to maintain normal respiratory movements under positive pressure have furnished a marked impetus to surgery of the chest.

Pneumothorax. Pneumothorax is the presence of air in the pleural cavity. Air may enter through a perforation in the lung, parietal pleura or esophagus. Pneumothorax complicating pulmonary tuberculosis results from rupture of a tuberculous cavity in the periphery of the lung. This complication would be far more common were it not for the attendant adhesive pleuritis which often involves both layers of pleura and prevents air from entering between them. Injuries of the chest may produce sucking wounds with resulting progressively increasing pressure within the pleural cavity.

The production of pneumothorax in chest operations formerly caused serious symptoms and even death. Appreciation of the knowledge that lung collapse is much decreased when the pleural layers are adherent and the mediastinum is fixed by inflammatory deposits, together with the experience that mediastinal flutter may be stopped by grasping and holding the lung or limiting or closing the thoracic opening, has led to the adequate handling of these cases. Pneumothorax is induced artificially to put the lung at rest, to obliterate cavities within it, and to stop bleeding from the

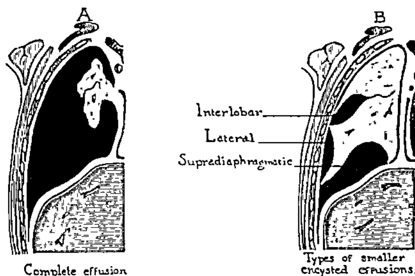


Fig. 282. FRONTAL SECTIONS THROUGH THE THORAX, SHOWING GENERALIZED AND ENCAPSULATED EFFUSIONS. (Modified from Testut and Jacob.)

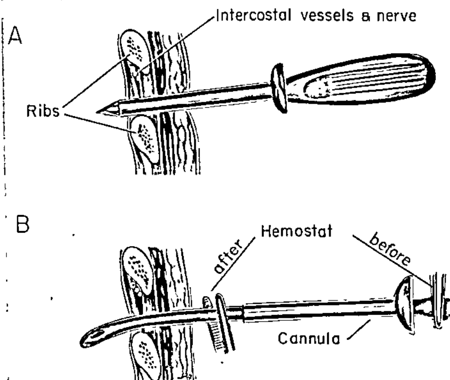


Fig. 283. TECHNIQUE OF CLOSED THORACOTOMY.

A, Trocar and cannula inserted correctly through an intercostal space, avoiding the vessels and nerve along the inferior margin of the uppermost rib. *B*, Method of preventing ingress of air while the catheter is being inserted. First hemostat on the end of the catheter is removed, and a second hemostat is put on near the patient as the cannula is removed. (From Sweet: Thoracic Surgery.)

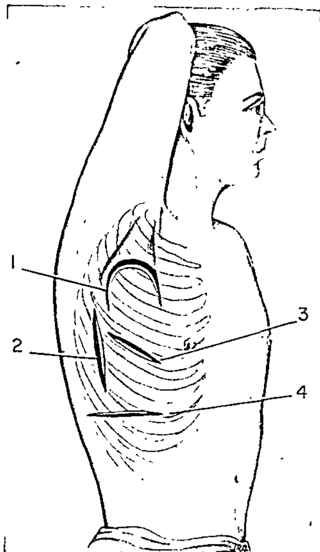


Fig. 281. MINOR THORACOTOMY INCISIONS FOR DRAINAGE OF EMPYEMA AND LUNG ABSCESS.

In the majority of cases when a short thoracotomy incision is required, a segment of rib must be removed. As in the drainage of other abscesses, for the drainage of empyema the most important consideration is to have the drainage tube at the bottom of the cavity. If that point is known, it is appropriate to make the incision through the soft parts in the direction of the rib to be resected. When there is uncertainty as to the deepest portion of the cavity, it is preferable to make a vertical incision through the soft parts so that, if the rib chosen for resection is too high, a segment of the next lower rib can be removed.

1, Inverted U-shaped incision for drainage of abscesses in the upper lobe of the lung. 2, Vertical incision over two or more adjacent ribs for drainage of empyema or abscess in the apex of the lung. For the latter it must be made between the medial border of the scapula and the spine. 3, Oblique incision in the direction of a rib, used in certain cases of empyema or pulmonary abscess where localization is accurate. 4, Transverse incision used in transpleural drainage of subdiaphragmatic or lower abscess. (From Sweet: Thoracic Surgery.)

displacing the heart and mediastinum, and even causing the interspaces of the affected side to bulge. More common than *total empyema* is that confined by adhesions to certain parts of the pleural cavity, *encapsulated* or *sacculated empyema* (Fig. 282; compare Fig. 281). The usual locations for encapsulated empyema are between the base of the lung and the diaphragm, supradiaphragmatic; between the lung and the chest wall, parietal; in an interlobar fissure; or between the mesial lung surface and the mediastinum. After rupture of a pulmonary lesion into the pleura the empyema may be interlobar or loculated from the start. The presence of pus and air in the pleural cavity is called *pyopneumothorax.*

Diagnostic aspiration or *thoracentesis* is of great importance, since it largely determines the therapeutic procedure. It is best carried out through the eighth or ninth rib interspace in the posterolateral aspect of the chest. Puncture below this level is unsatisfactory because it hits the costophrenic sinus (Fig. 284), and on the right side may puncture the liver. The most common varieties of pus encountered are the thin, stringy pus of streptococcal infection; the thick, yellowish or greenish pus of pneumococcal infection; and the seropurulent or serosanguineous exudate of tuberculous involvement.

Both the parietal and visceral pleurae change in empyema from thin, delicate membranes to markedly thickened, tough, fibrous and sometimes almost cartilaginous layers, with irregular surfaces covered by granulation tissue. These alterations, particularly in the visceral pleura, and the dense adhesions established are of serious consequence, since they limit, often to a marked degree, the expansile property of the lung, and prevent it from re-establishing normal relationships within the pleural cavity.

Surgical treatment of empyema is given to drain the pus (Fig. 281), relieve respiratory and circulatory embarrassment, decrease toxic absorption, obviate rupture, and obliterate the pus cavity. In addition, it prevents thickening of the pleural membranes and the formation of adhesions. Respiratory and circulatory changes are relieved readily by aspiration during the toxic stages. In fact, frequent aspiration cures certain empyemas. Surgical drainage by rib resection is not attempted early, since the sudden pressure change may result in shock from the sudden shifting of mediastinal

Fig. 285. LUNGS AND THEIR RELATIONS TO THE PLEURAE AND MEDIASTINUM.

Fig. 286. STRUCTURES ON THE LEFT SURFACE OF THE MEDIASTINUM.

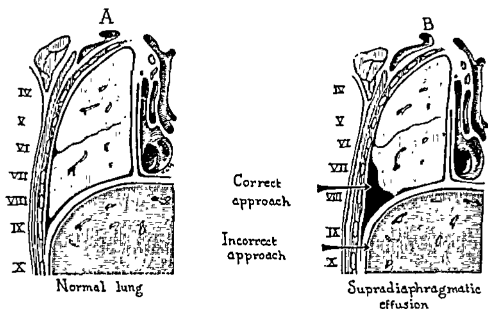


Fig. 284. FRONTAL SECTIONS THROUGH THE THORAX TO SHOW THE RELATIONS OF THE COSTODIAPHRAGMATIC SINUS TO THE LUNGS, DIAPHRAGM AND LIVER.

Incision low in this sinus fails to evacuate the effusion. (Modified from Testut and Jacob.)

structures. Subtotal evacuation by aspiration, with partial replacement by air, tides over the toxic phase, allows partial expansion of the lung, and, as the air is absorbed slowly, permits the mediastinal structures to return gradually to their normal position.

In certain cases of empyema in which for some reason it is impracticable to rely upon repeated thoracentesis with a needle, continuous aspiration by means of a catheter introduced through an intercostal space is advantageous (Fig. 283). The purpose of this method is to provide drainage which will avoid the ingress of air to the pleural cavity at a time when the lung might collapse because of its failure to become adherent to the chest wall. Its use in the management of empyema is therefore confined to those cases in which the fluid is thin with a low fibrin content, as in streptococcal infections.

If aspiration and rib resection fail to obliterate the empyema cavity, the more radical procedures of pulmonary decortication and thoracoplasty can be done.

An empyema, if left alone, may discharge its contents along any of a number of paths. Pus may break from the pleural cavity into a bronchus and be expectorated, forming a *bronchopleural fistula*. It may ulcerate through and discharge into the esophagus, pericardium, diaphragm or stomach, or may rupture externally through an intercostal space, *empyema necessitatis*, establishing a sinus. Large collections of pus have extended into the abdomen through the narrow intervals between the costal and vertebral attachments of the diaphragm and have continued along the spine, following the psoas muscle into the iliac fossa, there resembling lumbar and psoas abscesses.

Lungs and Their Thoracic Topography

Each lung is roughly a half-cone, its base resting on the diaphragm and its apex occupying the cervical dome of the pleura (Fig. 285). The mesial flat or concave surface lies against the mediastinum, and the outer convex wall against the rib cage. The soft and spongy tissue is molded against the walls of the chest cavity and bears the impress of the various structures to which it is related. The lungs are separated by a complete interpulmonary septum, the mediastinum or central compartment of the thorax, which extends from the sternum to the spine (Figs. 286, 287). The lungs are somewhat asymmetrical because of the higher level of the diaphragm on the right side and the decided projection of the heart to the left of the median line.

Anatomic Summary. The lateral or *costal surface* of the lung is smooth and convex, is accurately adapted to the chest wall, and presents a series of oblique grooves and ridges which correspond to the overlying ribs and rib spaces. It is traversed by a deep fissure which

with the vertebral column as it arches over the hilum of the right lung, takes a longer route, swinging away from the vertebrae and enclosing the accessory medial lobe as it does so. The anomalous vein, thus removed in its course by a distance of several centimeters from the mediastinum, is supported by a mesenteriole, which, derived from the parietal pleura, is sent inferiorly from the summit of the pleural cavity. This bilaminar pleural reflection, with the contained vein in its free lower margin, thus occupies the fissure between the upper lobe and its accessory portion. Thereby the superior portion of the pleural cavity is divided into two compartments which, below the free edge of the mesenteriole, communicate with one another.

In anatomic specimens the incidence has been found to be 0.4 per cent (seven cases of accessory lobe in 1637 cadavers). The radiographic incidence is 0.59 per cent (1936 cases in 323, 641 persons examined), as determined by study of the accumulated literature. The appearance of the anomaly, in roentgenograms, is characteristic: the pleural reflection is a narrow line; the azygos vein (within its pulmonary sulcus) suggests a tear drop (Fig. 289).

Thoracic Projection of the Borders and Lobes of the Lung. A knowledge of the surface projection of the lung borders and fissures affords the internist valuable aid in localizing pulmonary disease, and indicates to the surgeon the approach to the various types of encapsulated empyemas. The lung borders are indicated on the drawings which demonstrate the lines of pleural reflection (Figs. 279, 280).

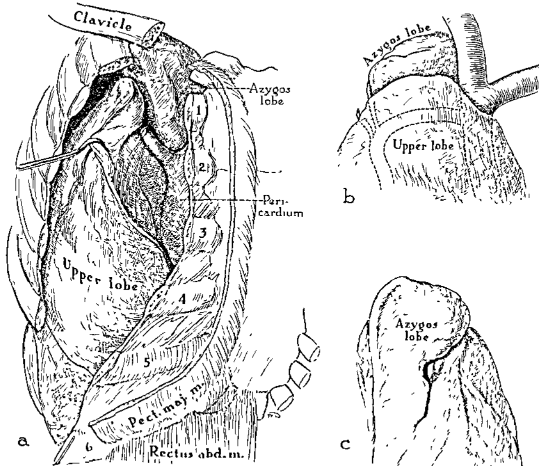


Fig. 288. ACCESSORY PULMONARY LOBE AND ANOMALOUS AZYGOS VEIN.

a, Contents of right pleural cavity, with the anomalous vein and the accessory lobe exposed by retraction of the upper lobe of the right lung. In this and the accompanying figures the mesoazygos has been removed. *b* and *c*, The azygos lobe and related pulmonary and vascular structures, seen from the lateral and medial aspects, respectively. (From Anson and Smith: Am. J. Roentgenol., 35: 630–34, 1936).

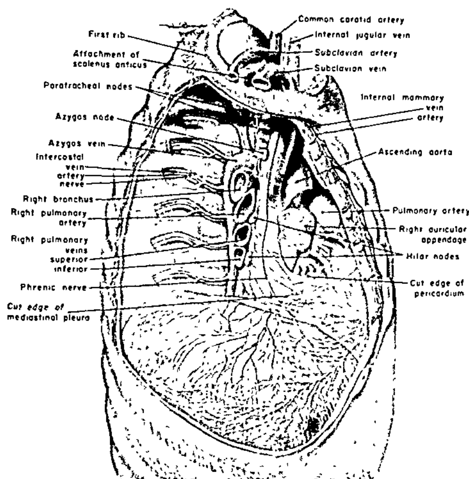


Fig. 287. STRUCTURES IN THE RIGHT SURFACE OF THE MEDIASTINUM.

Note the ease with which the thoracic esophagus can be approached after division of the azygos vein. Lymphatic drainage of the right lung is depicted. Collecting channels for practically the entire lung empty into the right paratracheal nodes either directly or indirectly by way of the nodes of the tracheal bifurcation. There is consistently a rather large node just above the azygos vein which drains the upper lobe primarily. Those in turn drain into the right paratracheal nodes. Efferent lymph vessels from these nodes join efferent vessels of the internal mammary chain to form the bronchomediastinal trunk. Ultimate drainage is to the venous system at the confluence of the internal jugular and subclavian veins. (From Connar: Surg., Gynec. & Obst., 101: 732–43, 1955)

travels obliquely inferiorly and anteriorly and terminates in the inferior free margin of the lung. This main fissure is deep throughout, extending to the hilum. It is the only fissure of the left lung, dividing it into superior and inferior or, better termed, anterior and posterior lobes. A second or subsidiary fissure is present in the right lung, beginning behind at the main fissure and running anteriorly and slightly superiorly to the anterior free margin of the lung. Thus three right lobes, a superior, middle and inferior, are delimited (Figs. 279, 280).

The medial or *mediastinal surface* is irregularly concave, its principal relationship being with the heart and pericardium. The most important part of this surface corresponds to the pulmonary hilum, which, on section, presents an oval outline. The inferior extremity of the hilum is continued into a fold of the pleura known as the pulmonary ligament. The structures grouped together at the hilum form the root of the lung. The hilum lies nearer the posterior than the anterior part of the lung, and somewhat nearer the apex than the base. The *apex* of the lung projects as a blunt cone above the plane of the thoracic inlet and fits accurately into the cervical dome of the pleura (Fig. 224), where it comes into close and surgically dangerous relationship with the thoracocervical (p. 235) and supraclavicular (p. 225) areas of the neck.

Among the infrequent types of pulmonary variation, the most striking is that in which a small accessory lobe is clasped by an aberrant loop of the azygos vein (Fig. 288). In such cases the vein, instead of remaining in contact

with the vertebral column as it arches over the hilum of the right lung, takes a longer route, swinging away from the vertebrae and enclosing the accessory medial lobe as it does so. The anomalous vein, thus removed in its course by a distance of several centimeters from the mediastinum, is supported by a mesenteriole, which, derived from the parietal pleura, is sent inferiorly from the summit of the pleural cavity. This bilaminar pleural reflection, with the contained vein in its free lower margin, thus occupies the fissure between the upper lobe and its accessory portion. Thereby the superior portion of the pleural cavity is divided into two compartments which, below the free edge of the mesenteriole, communicate with one another.

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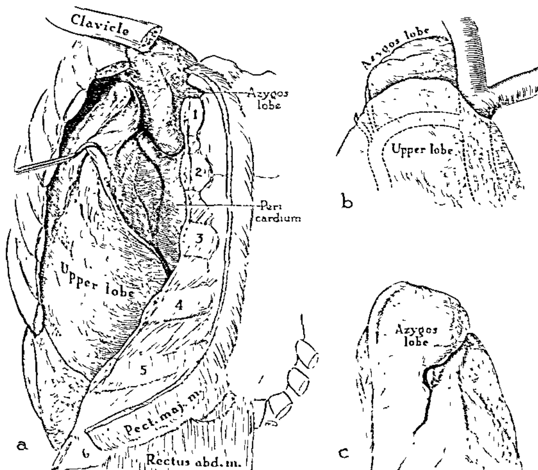


Fig. 288. ACCESSORY PULMONARY LOBE AND ANOMALOUS AZYGOS VEIN.

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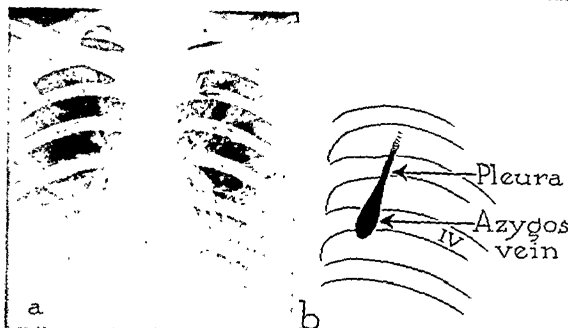


Fig. 289. ACCESSORY PULMONARY LOBE OF THE AZYGOS VEIN.

a, Roentgenogram of a female patient at St. Luke's Hospital, Chicago. The patient was 59 years old and weighed 220 pounds, *b*, Diagram to record the form and costal relations of the azygos vein and its mesenteriole; from the case illustrated in *a*. (From Anson, Siekert, Richmond and Bishop: Quart. Bull., Northwestern Univ. M. School, 24: 285-90, 1950.)

STRUCTURES IN THE LUNG PEDICLE AND THEIR RAMIFICATIONS. The structures in the root of the lung are the bronchus, the pulmonary artery and veins, the bronchial arteries, veins and lymphatics, the bronchial glands, the pulmonary nerve plexuses and the pulmonary ligament (Fig. 300). These structures are bound together with a small amount of connective tissue and pleura, which surrounds them as with a cuff.

As the *bronchi* enter the lung, the tubes become smaller by repeated division, and their coats become correspondingly thinner. The lining mucosa, which plays an important defense role against invasion of the parenchyma, is exceptionally thin in the smaller bronchioles. When bronchial dilatation occurs, its site is the fibrocartilaginous portion of the bronchus, which, then devoid of support, is transformed into a fusiform cavity.

In present-day study of the lung the guiding concept of structure depends upon the total branching of each bronchus (Fig. 290). Each lobe is regarded as being supplied by divisions of the main bronchus, each branch dividing to reach, and thereby to form, a definite portion of the lobe. The right upper lobe of the lung, for example, can be considered to consist of three portions on the basis of the triradiate splitting of the bronchus. The term "bronchopulmonary segment" is used to designate the portion of lung substance which is the total branching of a bronchus, and, in general, is limited to the subdivisions of lobes formed by the direct branches of the lobar bronchi. The terminology is conveniently arranged to make simple, direct correspondence between names of bronchial branches and subdivisions of the lung; and the subdivisions are named for their topographical position.

From the practical standpoint the following advantages may be mentioned: To the bronchoscopist the concept means that, in viewing the bronchial orifices, the latter may be immediately related to a definite portion of the lung and, thereby, may determine the position of a pulmonary abscess by the location of exudate in a bronchial orifice. To the radiologist the concept of bronchopulmonary relationship offers a satisfactory way of locating accurately the segmental site of a lesion or position of a foreign body. Additionally, the study may ultimately offer explanation for the phenomenon of predilection—by which the posterior segment of the upper lobe is the favorite site for tuberculosis, and by which bronchiectasis and pneumonia have their common sites.

The *pulmonary artery*, after leaving the right ventricle, runs a superior course of about 4 cm. a little to the left of the ascending aorta.

The right branch runs to the right lung behind the aorta, and the left branch runs to the left lung in the concavity of the aortic arch. In the lung pedicle the right ramus divides into two branches, and the left ramus is single. Their terminations spread out in a capillary network over the alveolar air cells, thus carrying impure venous blood from the right ventricle to the lung for aeration. A thrombus of the right side of the heart, of systemic venous origin, may release an embolus which would block a branch of the pulmonary artery and cause a suppression of that part of the lung so supplied. A massive embolus usually results in immediate death; with a more peripheral arterial block a *pulmonary infarct* (p. 304) develops which may degenerate into a pulmonary abscess.

The radicles of the *pulmonary veins* arise in, and carry the blood from, the pulmonary capillary plexuses about the alveoli. Their venules run in the interlobular spaces to enter, and form the trunks of, the large pulmonary

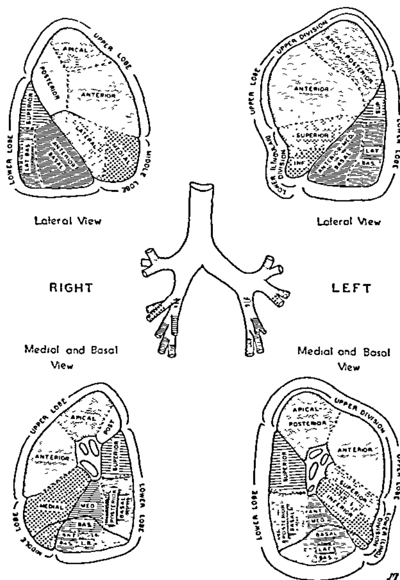


Fig. 290. TRACHEOBRONCHIAL BRANCHING CORRELATED WITH THE SUBDIVISIONS OF THE LUNGS; SHOWN IN THE FORM OF PULMONARY CHARTS.

Each bronchial branch is named on the basis of the portion of the lung to which it is distributed; the pulmonary subdivisions are marked by designs corresponding with those used in bronchial diagram. (From Jackson and Huber: Diseases of the Chest.)

veins. Two main trunks from each lung open into the left atrium on its lateral borders.

The *bronchial arteries*, rather than the pulmonary arteries, nourish the lung (see p. 335). They are small branches from the aorta or the aortic intercostal vessels, and vary from one to three in number. They accompany the bronchioles to the lung lobules.

Below the root of the lung, the two layers of pleura investing it come into apposition and are prolonged inferiorly as a distinct fold, the *pulmonary ligament*. This fold stretches between the pericardium and the inferior part of the mediastinal surface of the pleura and ends below in a free border.

Surgical Considerations

PULMONARY EMBOLISM AND INFARCT. The pulmonary artery carries to the lungs all the blood from the caval system of veins. It is an end artery with no collateral circulation, and is easily blocked by emboli arising in the systemic venous system. The most common source of these emboli is from phlebothrombosis, less often thrombophlebitis, arising in the deep veins of the calves. If main branches of the pulmonary artery are blocked by emboli, interference with lung function is so great that death occurs within a few minutes, usually before the operation of *pulmonary embolectomy* can be done. When minor arterial branches are plugged, only small areas of the lungs lose their function, and the patient survives; but the area becomes an avascular segment known as an *infarct*. The once frequent change of infarcts through infection to pneumonitis or abscess formation is now uncommon because of the use of antibiotics.

About a third of patients die with their first pulmonary infarct, and others with the second or third arterial obstruction. The mortality rate in the latter group has been greatly reduced by the immediate use of the anticoagulant drugs. Some use ligation of the superficial femoral or common iliac arteries to block emboli from leaving the site of the thrombotic process in the leg veins.

PRIMARY CARCINOMA OF THE LUNGS AND BRONCHI. Carefully evaluated evidence indicates that primary carcinoma of the lungs has definitely increased in recent decades; inhalation of tar dust from roads, coal smoke in large cities, and tobacco smoking are chiefly blamed. Symptoms are often late, particularly for tumors in the parenchyma, but a cough that hangs on in a patient previously well deserves careful diagnostic study. A tumor close to the pleura may produce a dry pleurisy or a pleural effusion characteristically bloody. Occlusion of a sizable bronchus often causes wheezing and complete obstruction, and results in an airless segment prone to become infected and develop into a pneumonitis or abscess. Apical or "superior sulcus" tumors may cause paralysis of the sympathetic trunks resulting in a Horner's syndrome, and brachial plexus involvement can give pain referred to the arm. Ulceration of the bronchial mucous membrane gives rise to blood-streaked sputum, characteristic of carcinoma of the lung. Cavitation of tumors with bronchial fistula, diaphragmatic pleurisy, recurrent nerve paralysis and even invasion of the esophagus and mediastinum sometimes occurs.

Diagnosis usually depends upon x-ray films and bronchoscopy, the latter being about 35 per cent effective.

Treatment should be open thoracotomy unless there is definite evidence of metastases or inoperable extension, in which case x-ray therapy is palliative. At operation an entire lung or a single lobe may be removed, but unfortunately five- or more year survivals are rare.

LUNG ABSCESS. A nontuberculous lung abscess is the result of destruction of pulmonary tissue by bacteria. The offending organisms are those found commonly in dental sepsis or tonsil infection: streptococcus, fusiform bacterium, spirochete of Vincent, and the anaerobic *Bacteroides melaninogenicus*. These bacteria may be aspirated with a foreign body, or with blood and tissue fragments, after mouth or throat operations, and may plug a small bronchus. By this mechanism an abscess or gangrene may develop. It is probable that an infarct may become infected by the aspiration of organisms. The postpneumonic abscess doubtless is caused by invasion of devitalized tissue. A mixed hematogenous and aspiration origin is not uncommon.

Spontaneous cures of lung abscess occasionally occur, and cures without operation are much more common now through the aid of antibiotics. Additional therapeutic procedures are repeated postural drainage and bronchoscopic aspirations of the abscess cavity. Sometimes an artificial pneumothorax will

collapse an abscess and allow it to heal. Bronchoscopy is advisable whenever a foreign body or new growth is suspected, or when the etiology of the abscess is obscure.

Operative treatment of lung abscess today is not drainage, except under most exceptional circumstances. The lesion is rare in private practice because all patients receive antibiotics at the hands of their personal physicians when there is a suggestion of pulmonary infection. This aborts most lung abscesses.

Those inflammations that are not seen early and that develop into an abscess can generally be cured by appropriate antibiotic management. Occasionally one will not respond and becomes chronic. The treatment is resection of that portion of the lung containing the abscess, usually meaning the removal of a segment or a lobe.

BRONCHIECTASIS. Bronchiectasis is a more or less extensive dilatation of part of the bronchial tree associated with infection. The disease is chronic and is remarkable for its large amounts of occasionally foul sputum. The epithelium lining the bronchi is destroyed, and the muscularis of the bronchial walls atrophies. The organisms passing through the ulcerated walls penetrate the alveolar tissue and give rise to multiple small abscesses. One lobe only may be affected, but both lungs may be involved uniformly. Bronchiectasis may follow the aspiration of a foreign body or may be occasioned by a tumor within, or pressing upon, a bronchus. Bronchiectatic lesions may be demonstrated by roentgenograms by the injection of a radiopaque oil (Lipiodol) through the larynx into the bronchial tree.

Early bronchiectasis resulting from the presence of a foreign body often is cured by bronchoscopic removal of that body. Bronchoscopic treatment is no more than palliative if infection has become well established and pathologic changes are advanced. In late stages the only curative treatment consists in the removal of the affected lobes or segments—*lobectomy, segmentectomy.*

PENETRATING WOUNDS OF THE LUNG. Wounds of the lung usually are accompanied by hemorrhage, the gravity of which depends upon the location of the lesion. The bleeding may be confined in the lung tissue and be spat up through a bronchus, or it may enter the pleural cavity, producing hemothorax. Wounds of the hilar zone are the most serious, since they may involve the large vascular trunks; those of the outer zones are relatively harmless, the hemorrhage accompanying them being rapidly absorbed. Lung hemorrhage must be differentiated from that due to a torn intercostal vessel. Hemothorax may become infected, forming *pyohemothorax.*

A noteworthy advance in surgery during World War II was the treatment of hemothorax by early complete evacuation of the

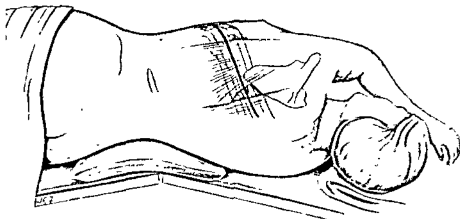


Fig. 291. STANDARD THORACOTOMY INCISION.

This incision, placed over the seventh rib and extending from close to the nipple line in front to almost the region of the vertebral column behind, provides adequate exposure for almost all operations on the lungs and mediastinal structures. Note the angulation of the table and the pillow to arch the site of the operation and thus widen the intercostal spaces. (From Sweet: Thoracic Surgery.)

clot through a long intercostal incision, and postoperative suction drainage. This obviated a possible pyohemothorax and prevented fixation of the lung and thoracic cage of the affected side by a thick, organizing clot, thus restoring the essential physiology of expansion and contraction of the chest and lungs.

Postoperative Pulmonary Atelectasis (Collapse). Atelectasis may be defined as the collapse of the whole, or any part, of a lung or both lungs, resulting from disappearance of air from the alveoli. This deflation of the lung, with its group of variable symptoms and signs, is the predominant postoperative surgical complication. The principal cause of postoperative atelectasis is retained bronchial secretions due to failure of the patient to cough them up. "Tenacious mucous plugs" are words commonly used in this connection, but on bronchoscopy few mucous plugs are found. Vigorous coughing will generally raise excess secretions.

The cardinal roentgenographic signs of a massive pulmonary collapse are elevation of the diaphragm and narrowing of the rib spaces on the affected side, displacement of the mediastinum and trachea toward the affected side, and lung shadow. All these signs result from the increased negative pressure which occurs with the disappearance of air in the involved lung distal to the obstruction.

The best management of this condition is prevention. Airways should be kept clear during an operation, and a patient should not be allowed to return to his ward or room until he has unobstructed breathing. Postoperative orders should include turning the patient every two hours, and frequent short intervals of deep breathing. Once atelectasis is present, increased efforts at hyperventilation should be carried out to aerate the affected parts: more frequent turning and deep breathing, the latter aided by carbon dioxide inhalations and the encouragement of coughing. For particularly tenacious sputum, tracheal and bronchial aspirations through a catheter or bronchoscope may be needed.

Approach to the Lungs and Mediastinum. There are particular circumstances requiring special approaches to the lungs and mediastinum, but most intrathoracic operations can be well performed through a long incision about the level of the seventh rib, curving from close to the nipple line to almost the region of the vertebral column behind, the *standard thoracotomy incision* (Figs. 291, 292). The decision to go through an intercostal space or resect a rib depends upon several factors. For children and young adults the intercostal approach is best. The thoracic cage spreads easily, the wound closure is more rapid, and there is

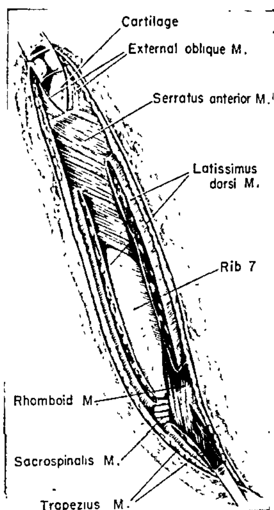


Fig. 292. Standard Thoracotomy Incision (Continued).

Latissimus dorsi muscle divided; posteriorly the lateral fibers of the trapezius are incised, and at or above the level of the seventh rib the rhomboids also. If the deeper incision is to be intercostal, the serratus anterior and external oblique muscles are divided at a point where their fibers which insert into the ribs can be avoided. If a rib is to be resected, the incision is made through the interdigitations of these muscles and their rib insertions.

Since postoperative pain not infrequently follows division or crushing of intercostal nerves, care should be taken to avoid these nerves and to use absorbable pericostal sutures for the closure of intercostal incisions. If in lower thoracic incisions there is permanent injury to the ninth or tenth intercostal nerve, an annoying flaccidity and bulging of the upper abdominal musculature may be noticed. (From Sweet: Thoracic Surgery.)

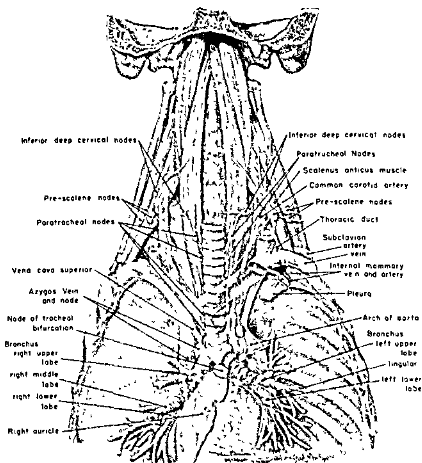


Fig. 293. RELATION OF PRESCALENE LYMPH NODES TO THOSE AT THE BASE OF THE NECK AND UPPER MEDIASTINUM.

The value of a prescalene and deep cervical lymph node biopsy in the diagnosis of various intrathoracic lesions is apparent. (From Connar: Surg., Gynec. & Obst., 101: 732–43, 1955.)



Fig. 294. OPERATION FOR PRESCALENE AND DEEP CERVICAL LYMPH NODE BIOPSY.

a, Prescalene fat exposed. *b*, Prescalene fat and contained lymph nodes being removed. *c*, Subsequent exposure of scalenus anticus muscle and phrenic nerve. (From Connar: Surg., Gynec. & Obst., 101: 732–43, 1955.)

clot through a long intercostal incision, and postoperative suction drainage. This obviated a possible pyohemothorax and prevented fixation of the lung and thoracic cage of the affected side by a thick, organizing clot, thus restoring the essential physiology of expansion and contraction of the chest and lungs.

POSTOPERATIVE PULMONARY ATELECTASIS (COLLAPSE). Atelectasis may be defined as the collapse of the whole, or any part, of a lung or both lungs, resulting from disappearance of air from the alveoli. This deflation of the lung, with its group of variable symptoms and signs, is the predominant postoperative surgical complication. The principal cause of postoperative atelectasis is retained bronchial secretions due to failure of the patient to cough them up. "Tenacious mucous plugs" are words commonly used in this connection, but on bronchoscopy few mucous plugs are found. Vigorous coughing will generally raise excess secretions.

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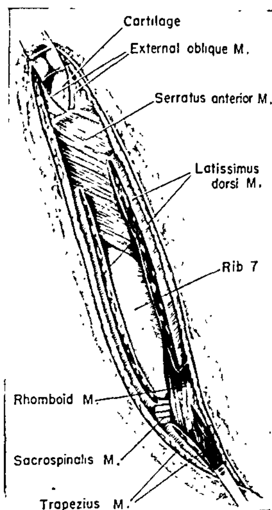


Fig. 292. STANDARD THORACOTOMY INCISION (CONTINUED).

Latissimus dorsi muscle divided; posteriorly the lateral fibers of the trapezius are incised, and at or above the level of the seventh rib the rhomboids also. If the deeper incision is to be intercostal, the serratus anterior and external oblique muscles are divided at a point where their fibers which insert into the ribs can be avoided. If a rib is to be resected, the incision is made through the interdigitations of these muscles and their rib insertions.

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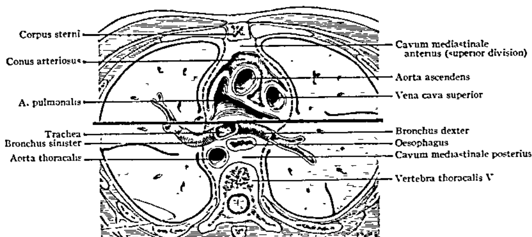


Fig. 296. CROSS SECTION THROUGH THE THORAX AT THE LEVEL OF THE BIFURCATION OF THE TRACHEA TO SHOW THE ANTERIOR AND POSTERIOR DIVISIONS OF THE MEDIASTINUM.

The division line is marked by a horizontal plane anterior to the tracheal bifurcation; the structures of the anterior and posterior divisions are enclosed by broken lines.

Fig. 297. FORM AND ANTERIOR MEDIASTINAL RELATIONS OF THE THYMUS IN A NEWBORN INFANT (FEMALE).

The gland is single, oval in outline and composed of compact glandular tissue. In these respects the thymus of the fetus and infant differs from the typical gland in the adult, in whom it is bilobed, digitiform and grossly adipose. (From Bell, Knapp, Anson and Larson: Quart. Bull., Northwestern Univ. M. School, 28: 156-64, 1954.)

less structural deformity. After thirty years of age, and particularly for elderly patients, the chest becomes more rigid, making wide separation more difficult and likely to produce annoying fractures of adjacent ribs. For these reasons rib resection works best for the older patients.

It is a simple matter to vary the standard thoracotomy incision for a higher or lower approach by resecting a rib or two above or below.

PRESCALENE AND DEEP CERVICAL LYMPH NODE BIOPSY. In 1949 Daniels* described a method of biopsy useful in diagnosing intrathoracic lesions when the diagnosis could not be established other than by thoracotomy. The procedure consisted of removing prescalene fat and contained lymph nodes. Connar well illustrates the anatomy (Fig. 293) and the operation in Figure 294. The incidence of positive diagnosis by this relatively minor procedure was 31 per cent, and the lesions most commonly found were carcinoma from the lung, Boeck's sarcoid, tuberculosis and Hodgkin's disease. If carcinoma of the lung is diagnosed by this procedure, a thoracotomy for excision of the primary lesion is only palliative and generally considered to be not worth while.

Mediastinum (Interpleural Space)

The mediastinum, or central compartment of the chest cavity, is the space between the lungs bounded by the posterior aspect of the sternum, the anterior surface of the spine, the two pleuropulmonary areas, and the diaphragm (Fig. 296; also Figs. 286, 287). It is not accurately median, but inclines somewhat to the left side. The mediastinum is shut off fairly securely from the abdominal cavity save at three main points: a narrow interval anteriorly between the sternal and costal attachments of the diaphragm, filled with loose connective tissue; the aortic opening posteriorly; and the esophageal hiatus.

Many surgically important structures lie in the mediastinum: the heart with the great vessels and the pericardium, the trachea and bronchi, the esophagus, aorta, nerves and lymph nodes. Until recently the region was considered inaccessible, but now it is explored extensively. Arbitrary subdivisions are valuable for descriptive purposes. The mediastinum is divided into anterior and posterior divisions by a frontal plane passing in front of the trachea and its bifurcation. The ANTERIOR MEDIASTINUM is divided into superior and inferior divisions by a transverse plane passing through the union of the first and second portions of the sternum which marks the level of the superior border of the heart. The *superior division* includes the thymus and the great vessels passing to and from the heart. The *inferior division* is occupied by the pericardium and heart (Figs. 295, 296). In the POSTERIOR MEDIASTINUM are the trachea, bronchi, esophagus, descending aorta, thoracic duct, azygos veins, and vagus and sympathetic nerves.

* Dis. of Chest, 16: 360–66, 1949.

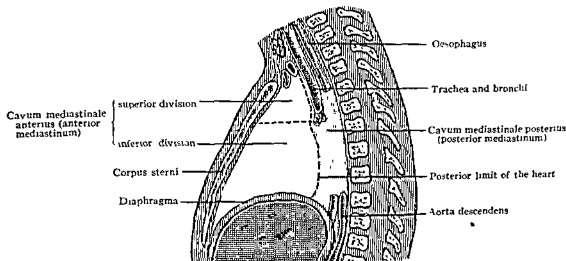


Fig. 295. DIAGRAMMATIC SAGITTAL SECTION THROUGH THE THORAX TO SHOW THE ANTERIOR AND POSTERIOR DIVISIONS OF THE MEDIASTINUM.

The anterior mediastinum is separated into superior and inferior divisions by the superior border of the heart. (Modified from Testut and Jacob.)

first two years of life, after which it normally regresses until in the adult it is replaced almost completely by adipose and connective tissue (Figs. 297, 298). In the newborn its two well developed, elongated lobes, which rarely are symmetrical, lie in the anterosuperior part of the retromanubrial region in front of the great vessels and the trachea. The lobes sometimes mold themselves over the upper circumference of the pericardial sac, and even may occupy a cervical position, reaching occasionally to the hyoid bone. *Thymic enlargement* produces tracheal compression causing noisy, difficult inspiration and expiration, known as *thymic stridor*. This is thought to progress to what commonly is called thymic asthma. Attacks of thymic asthma are believed to be precipitated by minor occurrences, and a few deaths on induction of anesthesia have been attributed to this cause. In patients suspected of having thymic asthma an intralaryngeal or intrabronchial foreign body should be ruled out by bronchoscopy.

Arteries of supply to the thymus are usually small branches of the internal mammary arteries (Fig. 296). However, the veins of drainage ascend between the thymic lobes to terminate, usually, in the innominate veins or in the superior vena cava (Fig. 185, p. 195). The veins which leave the lobes, although numerous, converge upon one or two vessels of vertical course.

INNOMINATE VEINS AND SUPERIOR VENA CAVA. The *innominate veins* (p. 235) unite at the inferior border of the first costal cartilage on the right to form the superior vena cava (Fig. 299). The *superior vena cava* runs an inferior course of about 4 to 5 cm., to the right

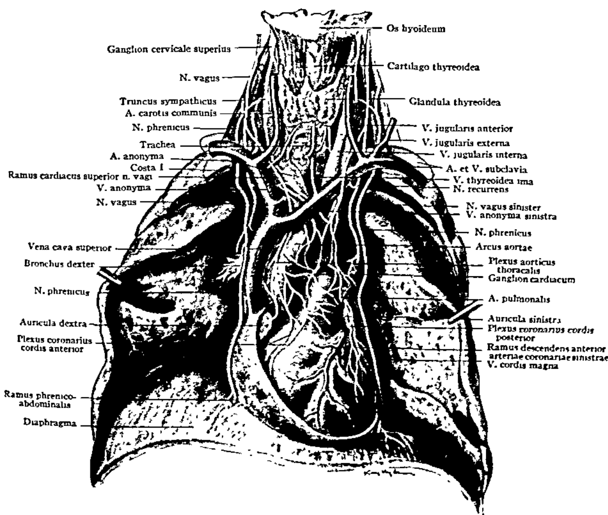


Fig. 299. ANTERIOR VIEW OF THE STRUCTURES IN THE SUPERIOR AND INFERIOR DIVISIONS OF THE ANTERIOR MEDIASTINUM.

ANTERIOR MEDIASTINUM

SUPERIOR DIVISION OF THE ANTERIOR MEDIASTINUM

Anteroposteriorly, the structures within the superior division of the anterior mediastinum are the thymus, a venous layer composed of the innominate veins forming the superior vena cava, an arterial layer made up of the pulmonary arteries, the aorta, and the innominate and left common carotid arteries. Between the vascular trunks of the area lie the vagus and phrenic nerves and the anterior mediastinal lymph nodes.

THYMUS. The thymus is a transitory structure, acquiring its greatest development in the

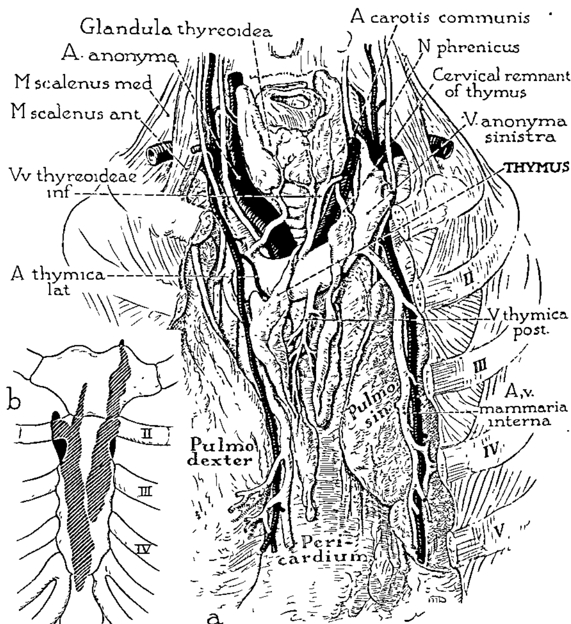


Fig. 298. ANATOMY OF THYMUS IN THE ADULT, EMPHASIZING THE FORM, VISCERAL RELATIONS AND BLOOD SUPPLY.

a, In this specimen, as is typical in the adult, the thymus is elongate and finger-shaped, consists of 2 parts, and has the gross appearance of paired fatty lobes. The thymic arteries are usually derived from the adjacent internal mammary arteries; at least some of the veins terminate in the left innominate (thymic bodies here retracted to expose the chief veins). The lobes occupy the sulcus between the anterior borders of the lungs, and may extend downward into the cardiac notch. *b*, Showing schematically the sternocostal relations of the thymus in the same specimen. In 66 per cent of 125 adult specimens studied the thymus ended inferiorly in the area between the third and fourth costal cartilages. (From Bell, Knapp, Anson and Larson: Quart. Bull., Northwestern Univ. M. School, 28: 156–64, 1954.)

sinuses. At the second right costal interspace the aorta is covered only by the thin anterior lappet of the right lung, so that, at this point, the aortic sound can be heard most readily. The ascending aorta is completely enclosed by the pericardium. The superior vena cava lies on its right, and the pulmonary artery on its left (Fig. 299).

The *arch* of the aorta lies behind the lower part of the sternal manubrium. It begins behind the right border of the sternum at the level of the second rib cartilage, and extends dorsally to the left to reach the spine at the left of the body of the fourth thoracic vertebra.

INNOMINATE, LEFT COMMON CAROTID AND LEFT SUBCLAVIAN ARTERIES. From the arch of the aorta branch the innominate, left common carotid and left subclavian arteries, in the order named (Figs. 299, 300).

Surgical Considerations

SURGICAL APPROACH TO THE THYMUS AND UPPER ANTERIOR MEDIASTINUM. Excision of the thymus gland is occasionally done because of considerable evidence of a relationship between abnormalities of this gland and myasthenia gravis. Three avenues of approach have been used: (1) transcostally through resection

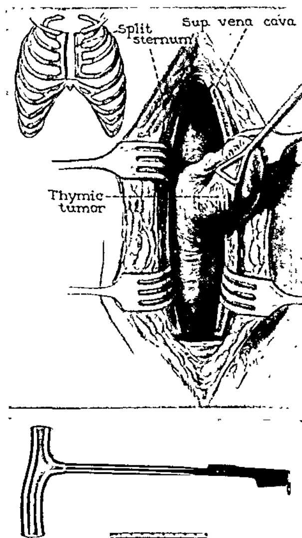


FIG. 301. STERNAL SPLITTING APPROACH TO THE THYMUS AND VERY LOW-LYING SUBSTERNAL GOITERS.

A midline skin incision is made from 2.5 cm. above the manubrium to the fourth costal cartilage. The sternum is exposed and divided with the Lebsche sternum splitter (lower insert) to within 5 cm. of the xiphisternal junction. At this point the sternum is divided transversely and the vertical split margins retracted, giving good access to the anterior mediastinal structures. (From Clagett and Root: Surg., Gynec. & Obst., 78: 397-401, 1944.)

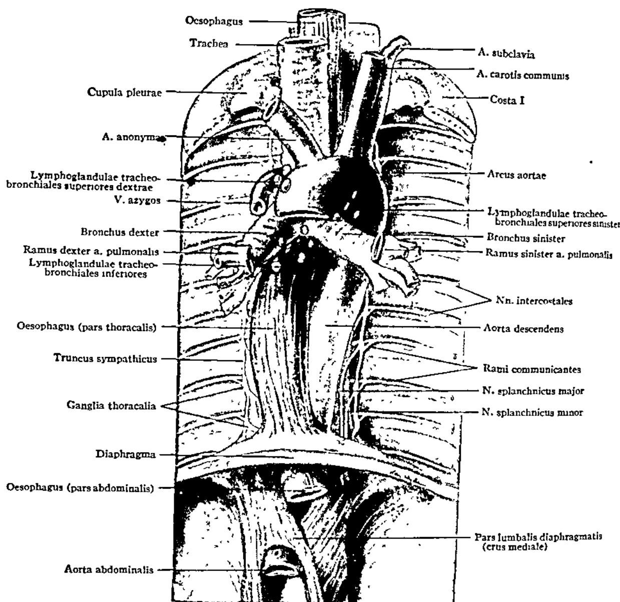


Fig. 300. TOPOGRAPHY OF THE TRACHEA, AORTIC ARCH AND ESOPHAGUS.

atrium. Its projection on the anterior chest wall corresponds to the first and second right intercostal spaces and the sternal extremities of the first two ribs. It is extrapericardial through most of its course.

Pulmonary Arteries. The trunk of the pulmonary artery, or the pulmonary aorta, directs the blood from the right ventricle to the lung. Throughout most of its course it lies within the pericardium at the base of the heart. From the superior border of the artery a short cord, the *ligamentum arteriosum*, runs to the inferior part of the aortic arch. This cord is the persisting portion of the *ductus arteriosus*, the fetal communication which diverted blood from the pulmonary artery to the systemic aorta, sidetracking the then nonfunctioning lungs. Incomplete occlusion of the duct occurs rather frequently, and generally is associated with a patent foramen ovale between the right and left atria. Both congenital defects make for insufficient aeration of the blood, and are common causes of death at birth and in early infancy. The mixture of venous and arterial blood causes the cyanosis of the "blue baby."

Ascending Aorta and Its Arch. The *ascending aorta* arises from the base of the left ventricle behind the left sternal margin opposite the third costal cartilage. The aortic bulb, the dilated origin of the aorta, contains three secondary dilatations, the aortic sinuses, which correspond to the three semilunar cusps of the aortic valve. The right and left coronary arteries spring from the corresponding aortic

sinuses. At the second right costal interspace the aorta is covered only by the thin anterior lappet of the right lung, so that, at this point, the aortic sound can be heard most readily. The ascending aorta is completely enclosed by the pericardium. The superior vena cava lies on its right, and the pulmonary artery on its left (Fig. 299).

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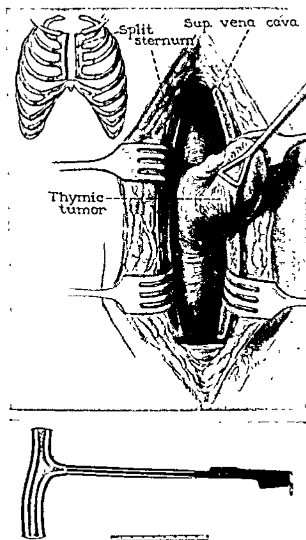


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of the right third and fourth ribs close to the sternum; (2) posterolaterally through a long resected area of the right fifth rib into the thorax and thence to the anterior mediastinum; and (3) the most direct, the sternal splitting route (Fig. 301). This last approach may also be advantageously used for low-lying substernal goiters.

CONGENITAL PULMONARY STENOSIS. Only in recent years has surgery had anything to offer to correct disturbed function due to congenital cardiovascular defects. Although it can only be briefly touched upon here, it is a pleasure to present the principles of some of the magnificent surgery of the heart and great vessels now being done for the relief of the "blue baby." The work of Blalock and Taussig in this field has been outstanding.

A common general type of abnormality which may be treated by operative means is that in which there is an inadequate pulmonary blood flow and in which mixed venous blood enters the arterial circulation. This is encountered most frequently in the tetralogy of Fallot, in which there is (1) pulmonic stenosis or atresia, (2) an interventricular septal defect, (3) an aorta which overrides the septal defect and receives blood from both ventricles, and (4) right ventricular hypertrophy (Fig. 302). While the pulmonic stenosis is the major defect in the tetralogy of Fallot, the cyanosis is due primarily to the fact that there is an interventricular defect with an overriding aorta which receives mixed venous blood from the right ventricle as well as oxygenated blood from the left ventricle. In such circumstances, if some of the inadequately oxygenated blood in the aorta were allowed to pass through the lungs as a result of the creation of an artificial ductus arteriosus, this shunted blood would take up oxygen and diminution in the cyanosis would result. Blalock brought this about by various procedures, but prefers an anastomosis between the proximal end of the subclavian

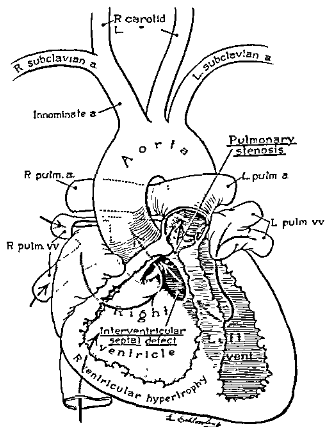


Fig. 302. DIAGRAM OF THE TETRALOGY OF FALLOT.

The four features are (1) pulmonic stenosis in the conus region, (2) an interventricular septal defect, (3) an aorta which overrides the ventricular septum and hence receives mixed venous as well as arterial blood, and (4) right ventricular hypertrophy. The cyanosis *in these cases* is due to the fact that the aorta receives inadequately oxygenated blood from the right ventricle as well as to the fact that the pulmonary blood flow is small as a result of the pulmonic stenosis or atresia (From Blalock and Taussig: J.A.M.A., 128: 189–202, 1945; Blalock: Surg., Gynec. & Obst., 87: 385–409, 1948.)

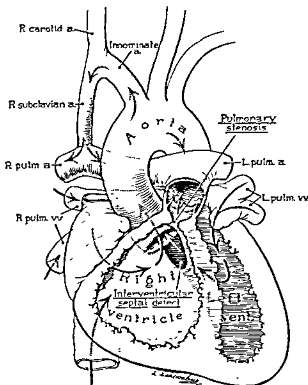


Fig. 303. DIAGRAM OF THE ALTERATION IN THE CIRCULATION FOLLOWING THE CREATION OF AN ARTIFICIAL DUCTUS ARTERIOSUS IN THE TREATMENT OF THE TETRALOGY OF FALLOT.

The anastomosis is between the proximal end of the subclavian artery and the side of the right pulmonary artery, which allows the shunted blood to pass to the right or left lung. The quantity of the inadequately oxygenated blood which is exposed to the oxygen in the lungs is greatly increased. (From Blalock and Taussig: J.A.M.A., 128: 189–202, 1945; Blalock: Surg., Gynec. & Obst., 87: 385–409, 1948.)

branch of the innominate artery and the side of one of the pulmonary arteries (Fig. 303). Potts and Smith (Fig. 304) produced the same result by a side-to-side anastomosis between the aorta and the left pulmonary artery. The type of anastomosis must often be varied to suit the conditions found at operation. Since the aortic or subclavian pressure is high and the pulmonic artery pressure is low, a good anastomosis results in the passage of a large quantity of improperly oxygenated blood from the aorta through the lungs. The mortality rate for such an operation is about 10 per cent. The majority of surviving patients show improved color, clubbing of the fingers and toes gradually recedes, incapacity lessens, and exercise tolerance is usually markedly increased.

SURGICAL CORRECTION OF AORTIC ARCH ANOMALIES. Great variations can be found in the origins and courses of the vessels which come from the aortic arch (Figs. 305 to 308). In the last two decades considerable success [illegible] l in correlating the clinical findings in one of these patients with the pathologic anatomy later detected at autopsy. More recently the roentgenologist has developed techniques for recognition of many of these malformations in the living subject. Within the past ten years the surgeon has been able to correct many of the conditions, with consequent relief of the patients' distress. Gross and Hubbard in 1939 were the first successfully to ligate a patent ductus arteriosus.

Increasing activity in the fields of cardiac and vascular surgery has served to revive interest in the developmental and adult anatomy of the aortic arches and the great vessels derived therefrom. Special interest, naturally, centers around the relation which anomalous arch, or arches, may bear to viscera in the neck and the thorax.

In the course of examination of specimens in the laboratory of gross anatomy, it became abundantly and strikingly evident that the "standard" type of branching from the aortic arch not only existed in the preponderant

number of cases (approximately in two of three), but also, when placed with a rather ordinary variation thereof, gave a combined total which represented over 90 per cent of cases in a series of 1000 specimens (Fig. 305).

In comparison with the profound variations presented, forty years ago, in the classical paper by Dr. Poynter (Fig. 307) the departures from the anatomic norm encountered in the senior author's laboratory seem relatively undramatic. In drawing upon an extensive literature, Dr. Poynter was able to give the reader

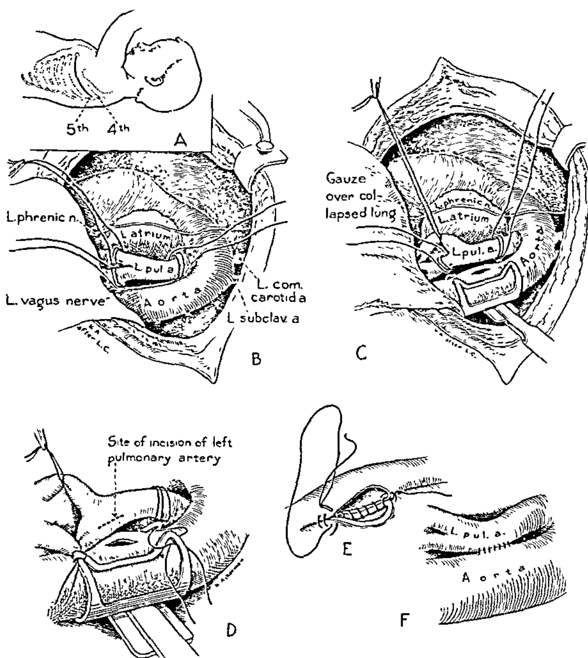


Fig. 304. CREATION OF ARTIFICIAL DUCTUS ARTERIOSUS BY SIDE-TO-SIDE ANASTOMOSIS BETWEEN THE DESCENDING AORTA AND THE LEFT PULMONARY ARTERY.

A, Long thoracotomy incision through the fourth intercostal space. *B*, Temporary occluding sutures around the left pulmonary artery. C, Special clamp applied to the aorta which occludes one edge for the anastomosis, yet allows blood to pass through a temporary lumen of about half normal caliber. *D*, Approximately 8-mm. lateral incision in the aorta, diagonal incision in the occluded pulmonary artery. *E*, Anastomosis suture of continuous fine black silk. (From Potts, Smith and Gibson: J.A.M.A., 132: 627-31, 1946.)

an imposing bibliographic history of such arterial anomalies, citing almost 1100 references.

The anomaly represented by the aberrant subclavian (Fig. 306) was seen in 1.3 per cent of the 1000 specimens (Fig. 305, Types VI to VIII) and assumes some importance in the adult as well as in the child as a cause of esophageal compression. The abnormal course of the "recurrent" laryngeal nerve, which accompanies this anomaly, is also important. The vascular ring, as produced by a persistent double arch, and those variants in which the ring is completed by the ductus, that may result in compression of the trachea and esophagus, were not observed, though these have been reported in the adult as well as in the pediatric group. A right aortic arch was found only once, in contrast to the high incidence reported associated with the tetralogy of Fallot. The statistical status of the latter groups thus appears relatively insignificant, but none the less assumes importance when viewed from the standpoint of pediatric surgery (Fig. 308).

Some of the types of variation in the aortic arch and its branches, encountered as surgical problems, did not occur among the dissection-room specimens. This is an expected circumstance, since these atypical patterns are likely to be associated with compression of the esophagus or trachea or with the tetralogy of Fallot. The former condition, if left untreated, often results in early death, owing to respiratory complications. Similarly, life expectancy in untreated cases of the latter sort is poor, indeed.

Edwards* has classified these anomalies on the basis of the source of the ductus arteriosus.

Group I: In this category belong those cases in which the arterial duct arises from the left pulmonary artery (Fig. 308, *a*, *b*, *c*, *e*, *g*, *i*).

Group II: The second group includes the cases in which the ductus arteriosus arises from the pulmonary artery of the right side (Fig. 308, *d*, *f*, *h*, *j*).

The functioning double aortic arch may show considerable difference in caliber of its two portions. The right arch is often the larger (Fig. 308, *a*); in some instances the left is so small as to become obliterated in some part of its course (Fig. 308, *b*).

A vascular ring is formed by a right-sided arch associated with a left subclavian artery which is derived from an aortic diverticulum with a left-sided ductus arteriosus (Fig. 308, *c*). The mirror image of this pattern is rare (Fig. 308, *d*). However, both conditions have been reported as causing tracheal or esophageal obstruction.

A variant of the above-described anomaly is represented by those cases in which the subclavian artery originates from the innominate artery (Fig. 308, *e*, *f*). Again a ring is formed, in this *schema* by the connection between the ductus arteriosus and the pulmonary artery.

As established by the examination of laboratory specimens, the aberrant right subclavian artery (Fig. 308, *g*) occurs with relative frequency among anomalies affecting the aortic arch (Fig. 305, *VI* to *VIII*). This anomalous condition often occurs in patients with the tetralogy of Fallot—as does a variant of this vascular pattern, namely, one in which the arrangement is its mirror image. Bahnson and Blalock** reported thirty-six such cases in a total of 841. The examples were equally divided between aberrant right (Fig. 308, *g*) and aberrant left (Fig. 308, *h*). Clinically, the presence of the anomaly gives rise to the condition known as dysphagia lusoria. Of additional importance is the fact that the right laryngeal nerve is not recurrent; with no vessel arising in such a manner as to draw the nerve downward in looping course, the nerve of the right side destined for the larynx passes directly to its area of supply (Fig. 306). In thyroidectomy or in tracheostomy the unusual (and, therefore, unexpected) position of the nerve constitutes a surgical hazard.

Even in those cases in which the succession of branches of the aortic arch is "normal" (Fig. 308, *i*) the position of origin of the innominate artery may assume surgical significance; tracheal pressure may be the result of origin of the artery farther to the left on the aortic arch or, comparably, by the left common carotid when the latter vessel arises farther to the right than it does in normal cases.

The right-sided aortic arch with a system of branching which is the mirror image of the typical pattern (Fig. 308, *j*) was encountered in 0.1 per cent of the present series (Fig. 305, *XV*). Self-evident is the importance of this arterial departure from the anatomic norm in selecting a site for thoracotomy in the Blalock-Taussig operation.

* M. Clin. North America, 32: 925–49, 1948.

** Ann. Surg., 131: 356–62, 1950.

number of cases (approximately in two of three), but also, when placed with a rather ordinary variation thereof, gave a combined total which represented over 90 per cent of cases in a series of 1000 specimens (Fig. 305).

In comparison with the profound variations presented, forty years ago, in the classical paper by Dr. Poynter (Fig. 307) the departures from the anatomic norm encountered in the senior author's laboratory seem relatively undramatic. In drawing upon an extensive literature, Dr. Poynter was able to give the reader

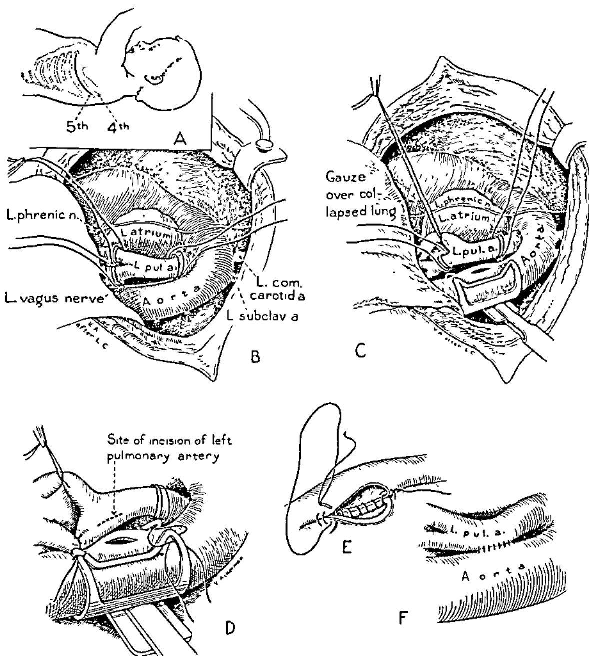


Fig. 304. CREATION OF ARTIFICIAL DUCTUS ARTERIOSUS BY SIDE-TO-SIDE ANASTOMOSIS BETWEEN THE DESCENDING AORTA AND THE LEFT PULMONARY ARTERY.

A, Long thoracotomy incision through the fourth intercostal space. *B*, Temporary occluding sutures around the left pulmonary artery. *C*, Special clamp applied to the aorta which occludes one edge for the anastomosis, yet allows blood to pass through a temporary lumen of about half normal caliber. *D*, Approximately 8-mm. lateral incision in the aorta, diagonal incision in the occluded pulmonary artery. *E*, Anastomosis suture of continuous fine black silk. (From Potts, Smith and Gibson: J.A.M.A., 132: 627-31, 1946.)

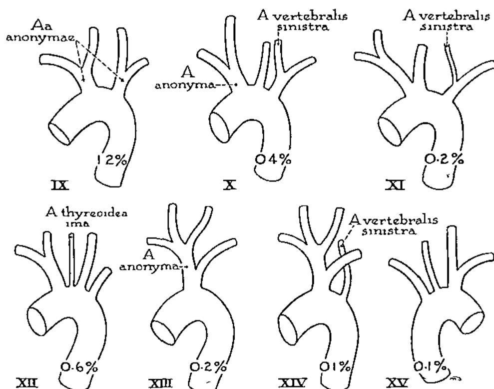


Fig. 305. TYPES OF BRANCHING OF THE AORTIC ARCH ENCOUNTERED IN 1000 ADULT CADAVERS.

I, The arrangement regarded as "normal" for man is actually encountered more frequently than all other types combined. In specimens of this variety 3 branches leave the arch, in the following succession from the specimen's right to left: innominate (with right common carotid and right subclavian as derivatives); left common carotid; left subclavian. *II*, An arrangement distinguished by reduction in the number of stems to 2, both common carotid arteries arising from the innominate. *III*, Here the distinguishing feature is increase, not reduction, in the number of derived branches. The left vertebral artery (usually arising from the subclavian) is the additional vessel *IV*, Differing from the preceding variety, the feature is replacement, the left vertebral artery (not the left common carotid, as in Type I) being the second stem in right-to-left succession. Both common carotid arteries arise from a common stem, as they do in examples of Type II. *V*, In this departure from the anatomic norm the left vertebral artery arises from the innominate, and the order of the left common carotid and left subclavian arteries is reversed. *VI* to *VIII*, Three patterns similar in respect to the position of origin of the right subclavian artery; the latter vessel arises as the last branch of the aorta arch, reaching the right upper extremity by passing dorsal to the esophagus. In respect to the origin of the other branches, the types differ. *IX*, A bi-innominate sequence, in which paired vessels (in turn having matching main branches) are the only derivatives of the aortic arch. *X* and *XI*, In both these varieties the left vertebral artery arises from an aortic trunk from which the left subclavian is also derived. However, in Type X a regular innominate artery is present (as in Type I), whereas in Type XI the "innominate" (with regular branches) arises from an aortic trunk shared with the left common carotid. *XII*, Here, as in Type III, an extra vessel arises from the arch between the innominate and the left subclavian; however, the added derivative is the *a. thyreoidea ima*, not the *a. vertebralis*. *XIII*, Unification is the distinguishing feature of this departure from the typical scheme of branching; the usual branches (see Type I) take origin from the aortic arch through a single trunk as an intermediary vessel. *XIV*, An infrequent variety with all branches derived from a common stem (as in Type XIII) with the exception of the left vertebral, which arises from the arch to the right of the common stem. *XV*, In this rare variety, in which the arch passes in a reversed direction from heart to thoracic aorta, the branches maintain a normal succession in relation to the body itself; however, their position on the aortic arch itself is as a mirror-image of the "standard" scheme of derivation. (From Liechty, Shields and Anson: Quart. Bull., Northwestern Univ. M. School, 31: 136–43, 1957.)

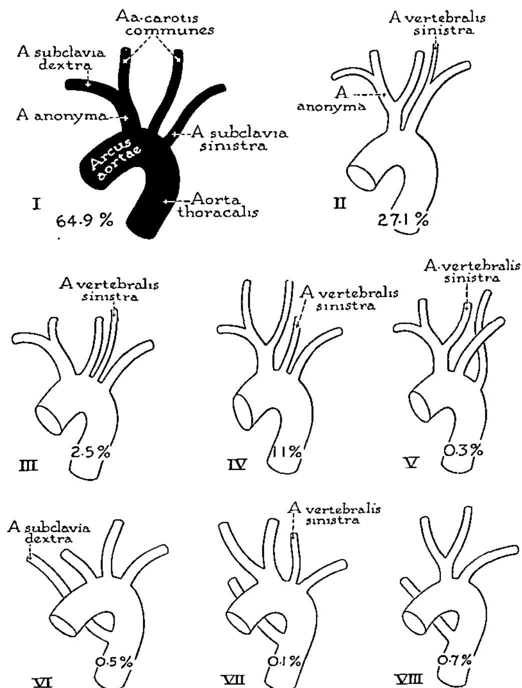


Fig. 305. (*See facing page for legend.*)

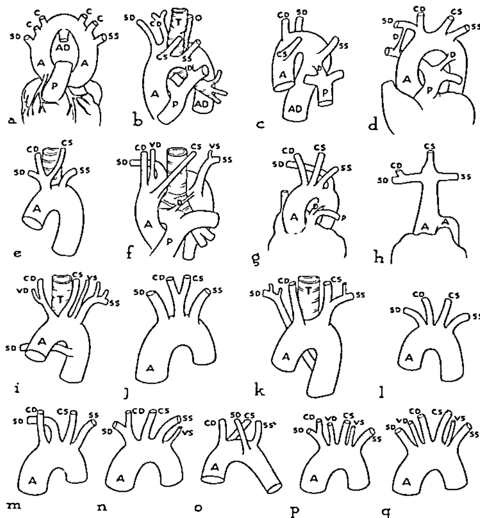


Fig. 307. EXAMPLES OF IRREGULAR BRANCHING OF THE AORTIC ARCH. (REDRAWN FROM POYNTER'S MONOGRAPHIC COLLECTION.)

a, True double aortic arch with 3 major trunks arising from each side of the arch (subclavian, internal carotid and external carotid). The descending aorta arises at the confluence of the 2 arches. *b*, An example of division of the aortic arch, the segments enveloping the trachea. The anterior division gives origin to the left common carotid and the left subclavian arteries and to a patent *ductus arteriosus*. *c*, A right aortic arch from which the left common carotid artery arises as the first branch, the left subclavian artery as the last. The latter artery shares a common short trunk with a patent *ductus arteriosus*. *d*, An aortic arch with persistent right and left arterial ducts, the former terminating in the right subclavian artery and the latter in the descending aorta. *e*, An arrangement in which the left common carotid artery takes origin from the innominate trunk, not from the aorta. *f*, A right aortic arch with the branches arising in the following order: right common carotid; right vertebral; common trunk for the left common carotid and the right subclavian, and left subclavian. The last also provides origin for the left vertebral artery and receives a patent *ductus arteriosus*. *g*, An arch in which the right subclavian artery arises as the last branch in the succession. This configuration is associated with atresia of the pulmonary artery, which, although leaving the heart as a fibrous cord, rapidly enlarges to normal caliber and is supplied by a patent *ductus arteriosus*. *h*, A case in which a single branch arises from the aortic arch, all other branches taking origin from it directly or indirectly. *i*, A specimen in which the right subclavian artery, or low origin, crosses posterior to the ascending aorta. The right vertebral arises from the right common carotid artery, the left vertebral from the aortic arch. *j*, An arch which gives rise to a single trunk for both common carotid arteries and a subclavian artery on each side of the median stem. *k*, Low origin of the right subclavian artery with the left common carotid and left subclavian arteries taking origin from a common stem. *l*, Specimen with independent origin of each of the common carotid and subclavian arteries from the aortic arch. *m*, A configuration differing from that in *e* in that the right subclavian arises as the second branch of the aortic arch. *n*, An arch similar to the "standard," except for the addition of a left vertebral which arises as the last branch. *o*, A case in which the right subclavian arises as the third branch of the arch, not, as is commonly the case, from an innominate artery. *p*, An aortic arch with 5 branches, the vertebral arteries arising as the second and fourth members in the sequence. *q*, An arch with 6 branches, the subclavian, common carotid and vertebral artery of each side being an independent aortic branch. (From Liechty, Shields and Anson: Quart. Bull., Northwestern Univ. M. School, 31: 136–43, 1957.)

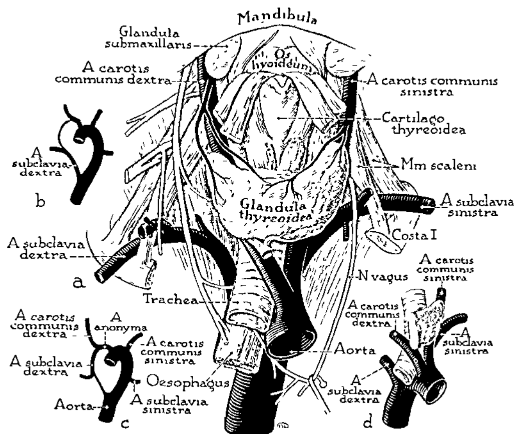


Fig. 306. RETRO-ESOPHAGEAL RIGHT SUBCLAVIAN ARTERY. DRAWINGS FROM A LABORATORY SPECIMEN, ACCOMPANIED BY SCHEMATIC FIGURES TO DEMONSTRATE EMBRYOLOGICAL CHANGES WHICH ACCOUNT FOR THE ANOMALOUS BRANCHING.

a, Deep cervical and thoracic structures, showing the relation of the anomalous artery to the trachea and the esophagus. *b*, Developmental establishment of a right subclavian artery as the last branch of the aortic arch; owing to subsequent disappearance of the thin segment between the common carotid and subclavian arteries of the right side, an innominate stem will be absent. *c*, Embryonic establishment of the usual pattern of branching of the aortic arch; as a result of disappearance of the short caudal segment of the right aortic arch, the cranial segment thereof will become the right subclavian branch of an innominate artery. *d*, A portion of the specimen shown in the main illustration; excision of the right lobe of the thyroid gland reveals the relation of the carotid and subclavian arteries and the intervening portion of the aortic arch to the trachea. (From Liechty, Shields and Anson: Quart. Bull., Northwestern Univ. M. School, 31: 136–43, 1957.)

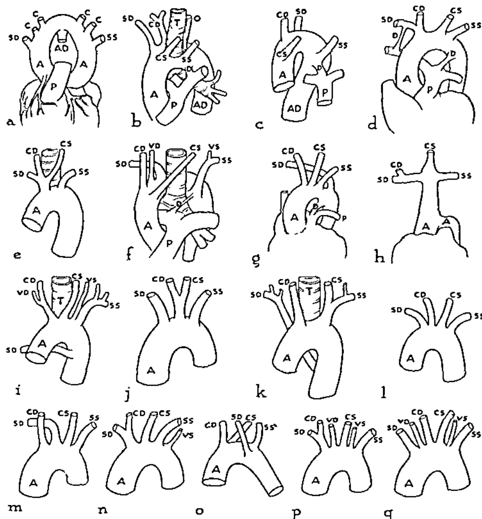


Fig. 307. EXAMPLES OF IRREGULAR BRANCHING OF THE AORTIC ARCH. (REDRAWN FROM POYNTER'S MONOGRAPHIC COLLECTION.)

a, True double aortic arch with 3 major trunks arising from each side of the arch (subclavian, internal carotid and external carotid). The descending aorta arises at the confluence of the 2 arches. *b*, An example of division of the aortic arch, the segments enveloping the trachea. The anterior division gives origin to the left common carotid and the left subclavian arteries and to a patent *ductus arteriosus*. *c*, A right aortic arch from which the left common carotid artery arises as the first branch, the left subclavian artery as the last. The latter artery shares a common short trunk with a patent *ductus arteriosus*. *d*, An aortic arch with persistent right and left arterial ducts, the former terminating in the right subclavian artery and the latter in the descending aorta. *e*, An arrangement in which the left common carotid artery takes origin from the innominate trunk, not from the aorta. *f*, A right aortic arch with the branches arising in the following order: right common carotid; right vertebral; common trunk for the left common carotid and the right subclavian, and left subclavian. The last also provides origin for the left vertebral artery and receives a patent *ductus arteriosus*. *g*, An arch in which the right subclavian artery arises as the last branch in the succession. This configuration is associated with atresia of the pulmonary artery, which, although leaving the heart as a fibrous cord, rapidly enlarges to normal caliber and is supplied by a patent *ductus arteriosus*. *h*, A case in which a single branch arises from the aortic arch, all other branches taking origin from it directly or indirectly. *i*, A specimen in which the right subclavian artery, or low origin, crosses posterior to the ascending aorta. The right vertebral arises from the right common carotid artery, the left vertebral from the aortic arch. *j*, An arch which gives rise to a single trunk for both common carotid arteries and a subclavian artery on each side of the median stem. *k*, Low origin of the right subclavian artery with the left common carotid and left subclavian arteries taking origin from a common stem. *l*, Specimen with independent origin of each of the common carotid and subclavian arteries from the aortic arch. *m*, A configuration differing from that in *e* in that the right subclavian arises as the second branch of the aortic arch. *n*, An arch similar to the "standard," except for the addition of a left vertebral which arises as the last branch. *o*, A case in which the right subclavian arises as the third branch of the arch, not, as is commonly the case, from an innominate artery. *p*, An aortic arch with 5 branches, the vertebral arteries arising as the second and fourth members in the sequence. *q*, An arch with 6 branches, the subclavian, common carotid and vertebral artery of each side being an independent aortic branch. (From Liechty, Shields and Anson: Quart. Bull., Northwestern Univ. M. School, 31: 136–43, 1957.)

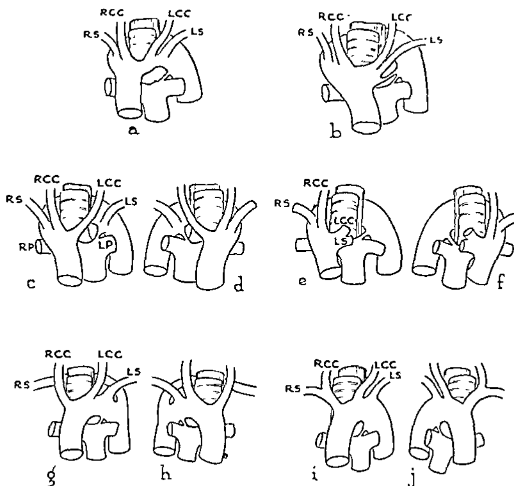


Fig. 308. SELECTED EXAMPLES OF SURGICALLY IMPORTANT ANOMALIES OF THE AORTIC ARCH AND OF THE DERIVED BRANCHES. (REDRAWN FROM EDWARDS).

a, Functioning double aortic arch. *b*, Partial atresia of double arch. *c*, Left-sided *ductus arteriosus* with right-sided aortic arch and left-sided descending aorta, the left subclavian artery originating from aortic diverticulum. *d*, Right-sided ductus with left-sided arch and right descending aorta, the right subclavian artery originating from aortic diverticulum. *e*, Left-sided ductus with right-sided arch and left descending aorta, the left subclavian originating from left innominate. *f*, Right-sided ductus with left-sided arch and right descending aorta, the right subclavian originating from the right innominate. *g*, Aberrant right subclavian artery arising as a branch of an otherwise normal arch. *h*, Aberrant left subclavian artery arising as the fourth branch of a right-sided aortic arch. *i*, Normal vascular pattern. *j*, Right-sided arch with branches forming a mirror image of the normal pattern. (From Liechty, Shields and Anson: Quart. Bull., Northwestern Univ. M. School, 31: 136-43, 1957.)

INFERIOR DIVISION, OR PERICARDIUM AND HEART

PERICARDIUM: ITS LAYERS, CAVITY AND RELATIONS. The *pericardium* is a closed fibroserous sac within which the heart and the proximal portions of its great vessels are enclosed. It is cone-shaped, and its base is directed inferiorly to a broad attachment at the diaphragm.

Between its visceral and parietal layers is the *pericardial cavity* (Fig. 309). Under normal conditions this is a potential space, with the serous walls in apposition. It becomes a true cavity when the walls are separated by fluid or air (hydropericardium, pneumopericardium). When the patient is in the erect position, pericardial fluid collects in the subcardiac reserve space or recess, which lies anteriorly between the attachment of the pericardium to the diaphragm and the inferior margin of the heart.

The anterior portion of the pericardium lies against the anterior chest wall, and is divided into extrapleural and retropleural areas by the pleural reflections which lie upon it. When the anterior mediastinal pleural sinuses extend over the pericardium to the midsternal line, all the front wall of the pericardium *is retropleural*, and there is no uncovered area. The extrapleural or uncovered area normally pres-

ent is of extreme importance from the surgical point of view, since it represents the only direct, accessible area of the pericardium where puncture can be made if pleural injury is to be avoided (p. 243). The intimate esophageal relations explain the difficulties in swallowing sometimes experienced in pericardial effusion and cardiac hypertrophy.

HEART IN GENERAL. The heart is a muscular organ so invaginated into the pericardium and so suspended by the great vessels at its base as to permit free movement (Figs. 309 to 311). It has two separate receiving and pumping stations, a right venous unit and a left arterial unit. The right unit collects the blood from the systemic veins and drives it through the lungs. The left unit receives the purified blood from the lungs into its atrium; its ventricle drives

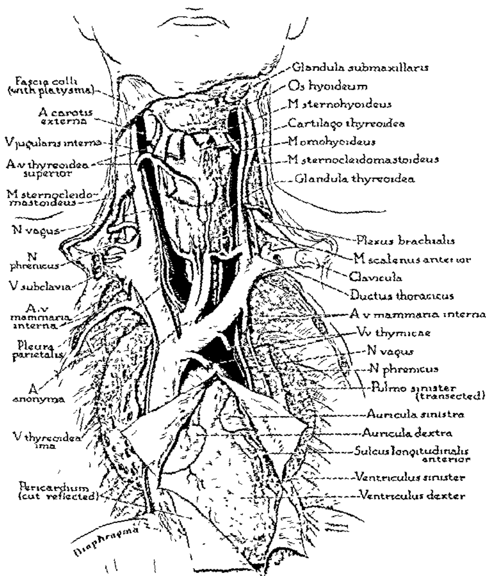


Fig. 309. THE THORACIC AND CERVICAL ANATOMY OF A MALE SPECIMEN, ESPECIALLY IN RELATION TO THE PERICARDIUM AND THE VASCULAR STRUCTURES INVESTED THEREBY.

The sternocleidomastoid muscles have been cut and turned aside The infrahyoid muscles have been transected, leaving short ends at their thyroid and hyoid extremities In this way the following have been exposed: thyroid cartilage and hyoid bone; jugular veins and carotid arteries; brachial plexus and scalene musculature, trachea; phrenic and vagus nerves; thoracic duct. The clavicles have been removed in their sternal portions, as have also the sternum and the sternal portions of the ribs. Within the thoracic cavity the lungs have been transected near each hilus. The pericardial sac has been opened to expose the heart and the ascending segment of the aorta The thymus has been removed, but its veins of drainage have been retained. (From Greig, Anson, McAfee and Kurth Quart. Bull., Northwestern Univ. M. School, 28: 66–75, 1954)

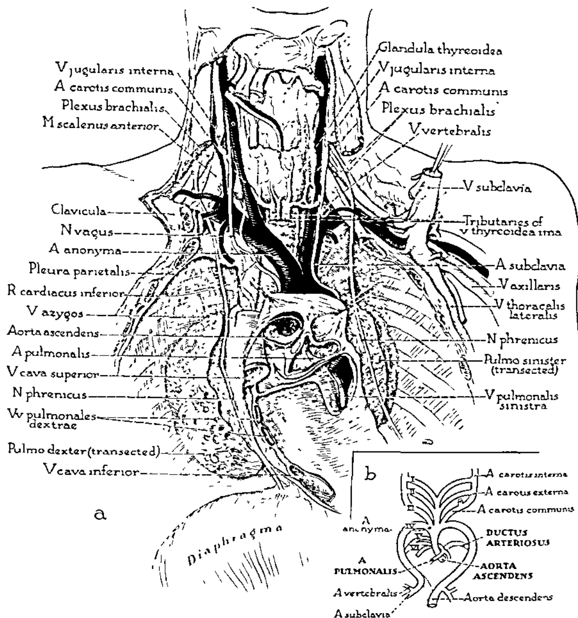


Fig. 310. THE RELATION OF THE SEROUS LAYER OF THE PERICARDIUM TO THE AORTA, TO THE BRANCHES OF THE LATTER'S ARCH AND TO THE PULMONARY ARTERY, SHOWN BY DEEPER DISSECTION OF THE SAME SPECIMEN; AND THE ORIGIN OF THE DUCTUS ARTERIOSUS AND OTHER DERIVATIVES OF THE VASCULAR ARCHES.

a, Major relationships are demonstrated by cutting along the line at which the parietal layer of the pericardium becomes continuous with the epicardium. It is shown that in this particular specimen, unlike certain others in the present series, no pericardial cul-de-sac is prolonged upon the ligamentum arteriosum; however, a shallow bay, marked by a star, came within 2 mm. of the inferior (pulmonary) extremity of the ligament. Additionally, by excision of the heart and reflection of the transected innominate veins, the following attendant features are demonstrated: the relation of the epicardium to the caval and pulmonary veins and to the aorta and pulmonary artery; the deep relations of the aortic arch and of the latter's branches in the neck. The crest between rami of the pulmonary artery is indicated by a short, straight arrow. A long, sinuous arrow passes through the transverse sinus. *b*, The transformation of the aortic arches (numbered *I* to *VI*) in the human embryo, shown schematically, in ventral view, with the vessels spread to the same plane. (From Greig, Anson, McAfee and Kurth: Quart. Bull., Northwestern Univ. M. School, 28: 66–75, 1954)

the blood throughout the general arterial system.

The thin partition separating the two atria, the *atrial septum*, has near its middle an oval depression, the *fossa ovalis*. This depression marks the patent fossa ovalis of fetal life, by which blood from the right atrium was sidetracked from the lungs and transmitted directly into the left atrium to be emptied into the left ventricle; from this chamber it was forced into

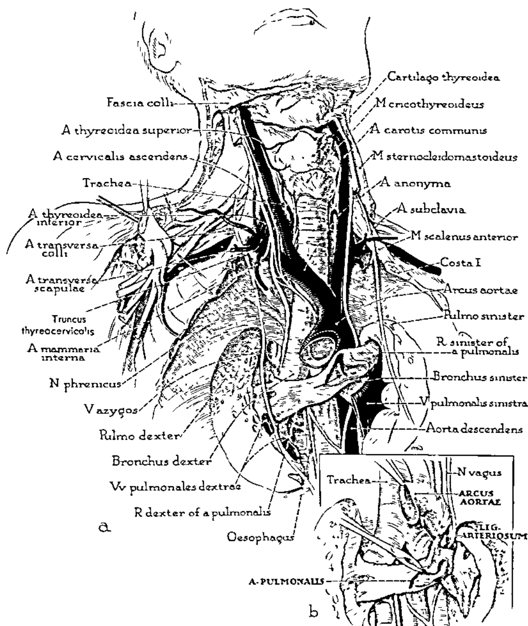


Fig. 311. ARTERIAL LIGAMENT, WITH ITS PULMONARY AND AORTIC CONNECTIONS, AND THE STRUCTURES SITUATED IN THE REGION OF THE LIGAMENT AT MIDDLE AND POSTERIOR MEDIASTINAL LEVELS, SHOWN BY CARRYING THE DISSECTION, IN THE SAME SPECIMEN, TO STILL DEEPER LEVEL; AND THE CONNECTIONS OF THE LIGAMENT.

a, The above-named anatomical structures are exposed by removal of the remaining portion of the serous layer of pericardium and of the connective tissue related to the aorta and pulmonary vessels, the trachea and bronchi and the esophagus. It should be noted that in this specimen the epicardium (whose lines of reflection are recorded on the aorta and pulmonary artery) did not reach the arterial ligament. In addition, the thyroid gland has been removed in order to reveal the branches of the subclavian artery, the vagus and phrenic nerves. The azygos vein, transected at the point of entry into the superior vena cava, appears at a more caudal level on the lateral margin of the esophagus. In the axilla the stump of the subclavian vein has been retracted, exposing the corresponding artery and the related elements of the brachial plexus (suprascapular nerve drawn upward, median nerve downward). *b*, The form, angular course and attachments of the ligament, demonstrated by elevating the transected aortic arch and by drawing the pulmonary artery downward. (From Greig, Anson, McAfee and Kurth: Quart. Bull., Northwestern Univ. M. School, 28: 66–75, 1954.)

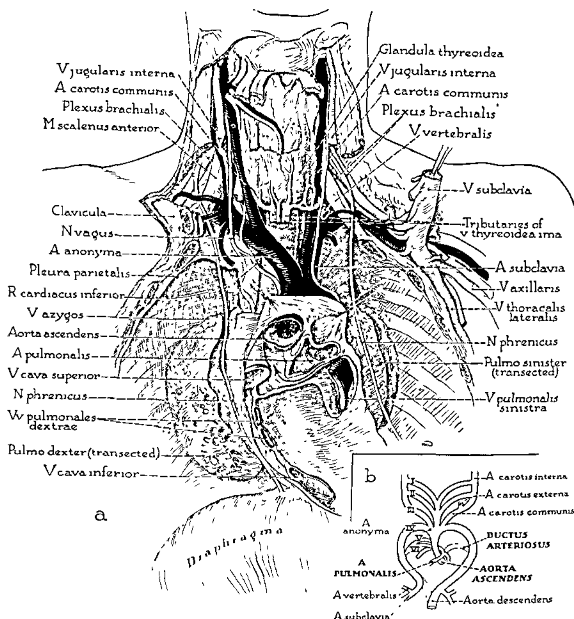


Fig. 310. THE RELATION OF THE SEROUS LAYER OF THE PERICARDIUM TO THE AORTA, TO THE BRANCHES OF THE LATTER'S ARCH AND TO THE PULMONARY ARTERY, SHOWN BY DEEPER DISSECTION OF THE SAME SPECIMEN; AND THE ORIGIN OF THE DUCTUS ARTERIOSUS AND OTHER DERIVATIVES OF THE VASCULAR ARCHES.

a, Major relationships are demonstrated by cutting along the line at which the parietal layer of the pericardium becomes continuous with the epicardium. It is shown that in this particular specimen, unlike certain others in the present series, no *pericardial cul-de-sac is prolonged upon the ligamentum arteriosum; however, a shallow bay, marked by a star*, came within 2 mm. of the inferior (pulmonary) extremity of the ligament. Additionally, by excision of the heart and reflection of the transected innominate veins, the following attendant features are demonstrated: the relation of the epicardium to the caval and pulmonary veins and to the aorta and pulmonary artery; the deep relations of the aortic arch and of the latter's branches in the neck. The crest between rami of the pulmonary artery is indicated by a short, straight arrow. A long, sinuous arrow passes through the transverse sinus. *b*, The transformation of the aortic arches (numbered *I* to *VI*) in the human embr shown schematically, in ventral view, with the vessels spread to the same plane. (From Greig, Anson, McAfee and Kur Quart. Bull., Northwestern Univ. M. School, 28: 66–75, 1954.)

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of the attachment of the third costal cartilage from points 2.5 cm. lateral to either sternal margin. This line is the clinical base of the heart, the line of demarcation from the great vessels. The normal extreme left margin of the heart is at a point a little inferior to the nipple in the left fifth intercostal space (Fig. 313).

An anteroposterior roentgenogram, with the tube 6 feet from the patient, shows a heart shadow accurate in outline. The location and shape of the heart can be seen to vary with the changes in position of the diaphragm. When the diaphragm is high, the heart lies in a more horizontal plane, the long axis through the base and apex forming a wider angle with the midsternal plane. In a long thorax with a low-placed diaphragm the heart hangs in a more dependent position in the chest cavity, its axial or base-apex line forming a more acute angle with the midsternal line.

The thoracic projection of the right atrium reaches from the third to the sixth costal cartilage and is about 1 to 2 cm. lateral to the right sternal border. The right ventricle corresponds to the left half of the sternum, and extends laterally to the left parasternal line from the third to the sixth left costal cartilage. The auricular appendix of the left atrium is the only part of that chamber that has a thoracic projection. This lies at the level of the sternal attachment of the left third costal cartilage. The dorsal projection of the left atrium lies at the level of the bodies of the seventh to ninth thoracic vertebrae. Only that small strip of the left ventricle, extending from the third to the sixth costal cartilage and forming the cardiac apex, can be seen from the front.

The *great vessel area* may be outlined by drawing a horizontal line across the sternum at the junction of the superior and middle thirds of the manubrium. This line should be a little less than 2.5 cm. inferior to the suprasternal notch, and should extend to the right and left a sufficient distance to permit the drawing of vertical lines to the lateral limits of the superior margin of the cardiac area.

Thoracic Projection and Areas of Maximum Audibility of the Heart Valves. In order to recognize the normal valve sounds and interpret properly pathologic findings by auscultation, it is necessary to locate the cardiac valves accurately (Fig. 313). Consideration must be given to the depth of the valves from the chest surfaces and to the sound-transmit-

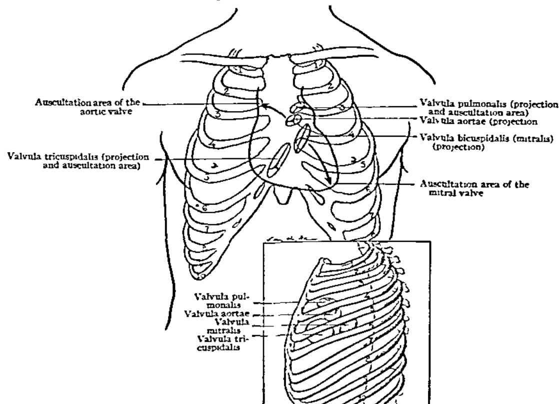


Fig. 313. THORACIC PROJECTION OF THE HEART VALVES AND THEIR AREAS OF MAXIMUM AUDIBILITY.

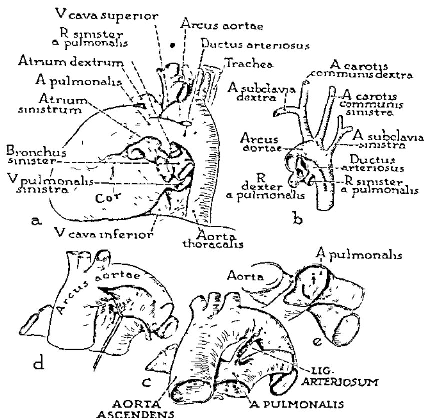


Fig. 312. ARTERIAL DUCT AND LIGAMENT; INFANTILE AND ADULT EXAMPLES.

a, The arterial duct (*ductus arteriosus*), pulmonary artery, aorta and related structures in an infant 6 days old; specimen viewed from the left. The trachea and the bronchi have been transected, the lungs removed; the great veins have been cut near their terminations, and the arteries derived from the aortic arch have been transected.

b, The arterial duct, the pulmonary artery, the aorta and the branches of the latter's arch in a 6-month fetus.

c to *e*, The arterial ligament (ligamentum arteriosum) in an adult male (past middle age), shown in relation to the point of bifurcation of the pulmonary artery and to the ventral wall of the aortic arch. *c*, The specimen viewed from the front, to demonstrate the form and continuities of the ligament. *d*, The same specimen, with the aorta opened from the ventral aspect, revealing the smoothness of the internal wall of the aorta in the area of attachment of the ligament. *c*, The specimen viewed from below, showing the pinpoint orifice (at arrow) of the arterial ligament. *e*, The specimen viewed from below, showing the pinpoint orifice (at arrow) of the arterial ligament on the anterosuperior wall of the pulmonary artery, where the latter divides into its right and left rami. (From Greig, Anson, McAfee and Kurth: Quart. Bull., Northwestern Univ. M. School, 28: 66–75, 1954)

the systemic circuit. A small portion of the fossa may remain patent after birth as a consequence of insufficient development of the heart, and cause a mixture of nonoxygenated blood to enter the general circulation (cyanosis).

Fixation of the Heart; Its Movements. The heart is held in position mainly by its connection with the great vascular trunks at its base. It is further supported by the pericardium, which is in relation with the lungs and mediastinal pleurae and has actual attachment to the diaphragm (Fig. 299). The right auricle is attached to the diaphragm by the inferior vena cava. Pathologic conditions arise in which the heart is displaced. For example, a large one-sided pleural effusion may displace the heart across the midsagittal plane to the uninvolved side, and pulmonary atelectasis may displace the heart to the side of the atelectasis.

The heart normally moves to the dependent side in the lateral recumbent posture and hangs more inferiorly in the standing position. In dorsal decubitus the heart so recedes from the chest wall that the apex beat may become imperceptible. In forced inspiration the heart descends perceptibly because of the attachment of the pericardium to the diaphragm.

Thoracic Projection of the Heart (Precordium) and Great Vessels. The *projection* of the heart on the anterior chest wall (precordium) is outlined approximately as follows. The superior border of the heart is represented by a line drawn across the sternum at the level



Fig. 315. STENOSED MITRAL VALVE.

a, The stenosed valve, seen from above. *b*, The same valve and the chordae tendineae of the first order shown after the heart had been opened. Thickening of the tendinous cords rendered opening of the valve difficult. The anterolateral commissure, at the reader's left, has been incised to simulate a normal appearance. (From Rusted, Scheifley and Edwards: Circulation, 6: 825–31, 1952.)

not necessarily stenotic, while one that admits two fingers may be mildly stenosed (*cf.* Fig. 315). Accessory cusps between the two major leaflets were seldom seen (approximately 5 per cent of cases). Because the posterior cusp is frequently notched, it is possible that other observers have considered one of these subdivisions of the posterior cusp as separating the main portions of the anterior and posterior cusps. In doubtful cases of this type the papillary muscles and chordae tendineae may be used to determine the site of the commissure, thus helping to make clear where the posterior cusp begins.

When the method of "finger fracture" is used, it is essential to remember that the weakest point will be the one to separate. Recalling that Dr. Rusted and his associates have found that the depth of the commissure in the normal valve averaged 0.7 to 0.8 cm. (and never more than 1.3 cm.), the surgeon palpating a stenosed mitral valve may conclude that a commissure deeper than 1 cm. is made up partly of fused cusps. It is reasonable to assume that a commissure made up partly of fused cusps would separate more easily than a thickened commissure with no fusion of cusps. Whether or not a thickened commissure, with no fusion of cusps, can be broken will depend on the severity and distribution of the rheumatic changes. Often the more severely involved valve with brittle commissural tissue can be "fractured," whereas the valve with nonbrittle, fibrous commissural tissue cannot be so broken.

Constrictive Pericarditis and Pericardial Effusion. Inflammatory lesions of the pericardium may modify the pericardial cavity and produce compression of the heart and its large vessels, either by contracting scar or the pressure of confined fluid. Rheumatic fever and tuberculosis are most commonly associated with the formation of fluid, but any pyogenic organism may be present.

There may be little interference with heart action, since the potential capacity of the pericardium is considerably greater than the volume of the heart and enclosed vessels, and a large quantity of fluid may collect slowly without untoward symptoms. On the other hand, a sudden effusion, as of blood following a cardiac injury, is not tolerated and results in immediate death.

As the pericardium becomes distended, its relations undergo important alterations. Generally the anterior lung margins recede and the pleural reflections withdraw laterally, forming an abnormally wide area of pericardium in contact with the anterior chest wall. Percussion reveals this increased area of cardiac dullness roughly triangular in outline, broad inferiorly and narrowing above. Heart sounds become inaudible and the cardiac impulse indistinct.

Subsidence of the acute infection commonly leaves adhesions and scar tissue which increase in density, so that in some cases the entire heart may be constricted to a poorly functioning small organ, and/or there may be unequal and embarrassing compression over various parts of the heart, such as the short portions of the superior and inferior venae cavae lying within the pericardium, or over the right atrium, right ventricle, left ventricle or pulmo-

ting quality of the intervening tissue, as well as to the direction of flow between the heart chambers. Of the four valves, the right atrioventricular (tricuspid) and pulmonic lie nearer the surface than the left atrioventricular (mitral) and aortic valves.

The *right atrioventricular (tricuspid) valve* is located posterior and lateral to the lowermost quarter of the sternum behind the attachments of the right fourth, fifth and sixth costal cartilages. Its area of greatest audibility is directly over its surface projection. The *pulmonary valve* lies mainly posterior to the third left costal cartilage, and the clearest sound of its closure is heard directly over its location in the second left interspace. The *left atrioventricular (mitral) valve* lies at a much deeper level than the valves of the right side of the heart, and is located posterior to the left half of the sternum on a level with the fourth costal cartilage. Its auscultatory area is in the direction of the blood flow from the atrium to the ventricle, and is over the apex of the heart, where the tip of the ventricle is in apposition with the chest wall. The *aortic valve* is overlaid in part by the pulmonary valve, and is located posterior to the left sternal margin and the mesial part of the left third interspace. The sound of its closure is projected along the course of the blood stream and may be heard best in the second right interspace at the sternal margin.

VESSELS AND NERVES OF THE HEART. The *arterial supply* of the heart muscle is derived from the right and left coronary arteries, which spring from the aortic sinuses. Their origins are hidden anteriorly by the right auricular appendix and the pulmonary artery (Fig. 309). The right coronary artery runs in the right portion of the coronary sulcus between the auricular appendix and the right ventricle. The left coronary artery is hidden at its origin by the pulmonary artery. Its short trunk divides into a descending ramus which runs down the anterior interventricular groove toward the apex, while the posterior circumflex branch is more horizontal and runs in the coronary sulcus to be distributed to the posterior portion of the heart. Coronary sclerosis or spasms, with obliteration of the arterial supply producing cardiac ischemia, may be the pathologic basis of angina pectoris.

Most of the *veins* of the heart enter the coronary sinus, a wide venous channel situated deep in the posterior part of the coronary sulcus. It opens into the right atrium between the atrioventricular orifice and that for the inferior vena cava.

The *nerves* forming the cardiac plexus, which spreads over the aortic arch and heart, are derived from the vagus (Figs. 310, 311) and from the cervical gangliated chain (p. 202).

Surgical Considerations

VALVULAR STENOSIS. As recently described and figured by Drs. Rusted, Scheifley and Edwards, from an examination of the mitral valve in fifty normal hearts, it has been made clear that features of clinical interest have not received deserved attention in textbooks of anatomy. New information is becoming increasingly important because it aids in explaining both the genesis of mitral stenosis and the surgical means for its correction.

In none of the hearts examined did the valve orifice extend all the way to the ring; that is, there was always some junctional or commissural tissue between the two cusps of the mitral valve in this series of cases (Fig. 314). With few exceptions, the depth of this tissue ranged between 0.5 and 1.0 cm. The figures representing the intercommissural diameter of the valve, with the heart held in the closed position, show a considerable range above and below the equivalent of two fingerbreadths (roughly 2.5 to 3.5 cm.). Thus a valve less than two fingerbreadths from commissure to commissure is



Fig. 314. NORMAL FORM OF A MITRAL VALVE.

Showing the junctional tissue or commissures (at arrows) between the 2 cusps of the valve. Because such tissue invariably occurs, the valve orifice does not extend all the way to the ring. Here the valve has been opened by an incision through the middle of the posterior cusp. (From Rusted, Scheifley and Edwards: Circulation, 6: 825-31, 1952.)



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nary artery. Calcium is often deposited in the scar and may invade the heart muscle.

The triads of Beck make the diagnosis of cardiac compression simple and infallible. Those for acute compression are (1) a rising venous pressure, (2) a falling arterial pressure, and (3) a small, quiet heart. The pulse weakens, and signs of arterial failure appear. The chronic compression triad consists of (1) ascites, (2) a high venous pressure, and (3) a small, quiet heart. Ascites may become enormous, and the liver and spleen undergo enlargement.

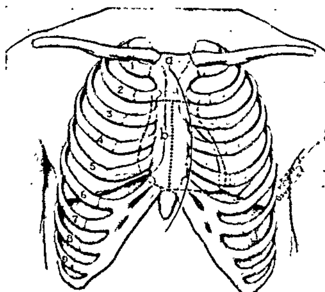


Fig. 316. STEPS IN PERICARDIECTOMY.

a, Skin incision curved laterally to avoid its lying directly over the sternal incisions. *b*, Xiphisternum excised and the sternum crosscut in the second interspace. The sternum is then divided vertically. The pleurae are then displaced laterally, since wide retraction is made to expose the pericardium. Rents in the pleura are unimportant, because intratracheal pressure anesthesia is used. (From Holman and Willett: Surg., Gynec. & Obst., 89: 129–44, 1949.)

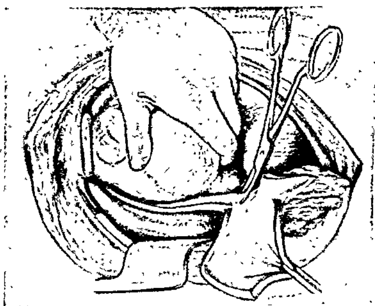


Fig. 317. PERICARDIECTOMY (CONTINUED).

Careful dissection has removed the greatly thickened and calcified pericardium from the region of the left phrenic nerves medialward over the left and right ventricles. Superiorly, the pulmonary artery, aorta and superior vena cava are freed. The right border of the heart is cleared so as to give a good view of the superior vena cava, right atrium and inferior vena cava. Inferiorly, from the apex of the left ventricle to the inferior vena cava, the thick pericardium lying between the heart and diaphragm is excised. (From Holman and Willett: Surg., Gynec. & Obst., 89: 129–44, 1949.)

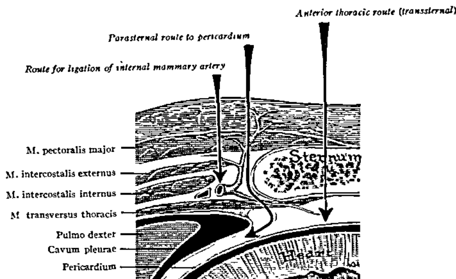


Fig. 318. SCHEMATIC CROSS SECTION THROUGH THE STERNAL REGION, PASSING THROUGH THE LEFT FIFTH INTERCOSTAL SPACE, TO SHOW THE RELATIONS OF THE INTERNAL MAMMARY ARTERY TO THE LEFT PLEURAL SINUS AND TO THE PERICARDIUM.

(Modified from Testut and Jacob.)

The operation of pericardiectomy (Figs. 316, 317) is designed to release the heart from its constricting sac. Holman has emphasized the need for liberating all borders of the heart, including excision of the pericardium lying between the heart and the diaphragm, and freeing both venae cavae. Complete restoration of the sick to normal commonly follows thorough surgery.

PARACENTESIS OF THE PERICARDIUM (PERICARDIOCENTESIS). Puncture or paracentesis of the pericardium is the piercing of the pericardium for withdrawal of its contents. This may be done as an exploratory or therapeutic procedure (Fig. 318). The selection of a site for the introduction of the needle must avoid the internal mammary vessels, pleura and heart. It should reach the largest collection of fluid in a favorable position for aspiration and, if deemed necessary, for incision.

Avoiding the internal mammary vessels is so important that all points of election for puncture lie lateral or mesial to them.

All the interspaces from the third to the seventh, either close to the sternum or lateral to the vessels, are satisfactory.

The danger incident to puncture of the pleura has been disregarded despite many reported instances of pleural infection following pericardial tap in septic cases. As one often is doubtful of the kind of fluid in acute cases, it is safer to introduce the needle at a point where it is unlikely to injure either pleural sac. The diagrams of the pleural reflections (p. 293) show that the risk of injuring the pleura will be least if the needle is introduced through the anterior extremity of the fifth or sixth intercostal space, close to the sternum. The extreme narrowness of these spaces renders this a little difficult, especially since the interspace at this level often is reduced to a slit, and even that is blocked partially by cartilage. The sixth space is an excellent site for puncture, since it overlies directly the large subcardiac pericardial recess, within which the bulk of the pericardial fluid is obtained; there is little risk of wounding the heart at this level. It rarely will be necessary to penetrate deeper than 2.5 cm., since the distended pericardium lies in close apposition to the sternochondral wall. The extreme thickness and toughness of the pericardium in some cases of purulent pericarditis make paracentesis difficult, as do adhesions of the serous layers and marked dilatation of the heart with only a limited effusion. The possibility of injuring the heart or a coronary vessel is a source of anxiety. The reasons for the election of puncture rather than open incision are its safety and simplicity.

PERICARDIOTOMY. Pericardiotomy, or incision into the pericardium for the exposure and drainage of a purulent effusion, may be done after *subperichondrial excision* of the fifth left costal cartilage.

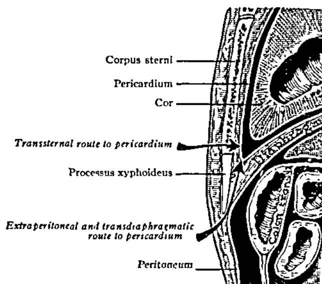


Fig. 319. SCHEMATIC SAGITTAL SECTION THROUGH THE STERNAL REGION TO SHOW THE ANTERIOR RELATIONS OF THE PERICARDIUM.
(After Testut and Jacob.)

The internal mammary vessels are exposed, those lying on the transversus thoracis (triangularis sterni) muscle. Incision is made through the perichondrium of the excised cartilage. More extensive exposure may require similar excision of the fourth and sixth cartilages. Greater access is obtained by chipping away the left border of the sternum. When the internal mammary vessels have been ligated, the transversus thoracis muscle is divided, and the pericardium with its thin covering of mediastinal fat is exposed. The fat is wiped aside, and the left pleural reflection is identified and displaced laterally with the fingers. The pericardium then is opened and drained.

The procedure may be carried out through a *transsternal approach* (Fig. 319; *cf.* Fig. 318). A trephine opening is made in the sternum to avoid injuring the blood vessels and the margins of the pleura. By this route the point of greatest and most dependent pericardial accumulation may be reached. By means of blunt dissection the endothoracic fascia, the fibers of the triangularis sterni muscle (transversus thoracis) and the pleural margins may be pushed away. The pericardial sac can be seized, drawn into the opening, incised and drained. The pericardium also may be exposed *inferior to the inferior end of the sternum.* This approach is simple, requires but little time, and drains freely the lowest available part of the cavity.

Exposure of the Heart. The heart may be exposed adequately by either of two methods, median sternotomy or intercostochondral thoracotomy. In *median sternotomy* the skin is incised from the level of the second interspace to the midpoint between the umbilicus and the xiphoid. The overlying structures are freed from the sternum, which is split lengthwise to the upper level of the skin incision, at which point the bone is cut across. The xiphoid is removed or is displaced laterally, and the internal mammary vessels are carefully avoided. The halves of the sternum are retracted and the pleura is pushed aside, after which the anterior portion of the diaphragm and peritoneum are incised. The pericardium is opened widely by an incision extending to the pericardial reflection over the diaphragm, and the heart is brought well into view.

In *intercostochondral thoracotomy* an incision is made in the left fourth intercostal space from the anterior axillary line to the lateral border of the sternum. The third, fourth, fifth and sixth costal cartilages then are sectioned, the internal mammary vessels are ligated, and the incision is carried into the pleura. The superior and inferior T flaps are retracted, and the pericardium is opened. The left lung, left ventricle and part of the right ventricle are exposed.

POSTERIOR MEDIASTINUM

The posterior mediastinum lies behind a frontal plane which passes in front of the bifurcation of the trachea and the posterior surface of the heart. The most important structures contained in the abundant areolar tissue characteristic of the compartment are the trachea, bronchi, thoracic esophagus, descending part of the thoracic aorta, thoracic duct, sympathetic gangliated trunk, and azygos vein with its tributaries (Figs. 300, 327). Abscesses from spontaneous or traumatic rupture of the esophagus, or from tuberculosis of the vertebral body, are fairly common here.

Mediastinal Trachea and the Primary Bronchi. The thoracic part of the trachea runs from the superior margin of the sternum to the level of the junction of the first and second portions of the sternum, where it bifurcates into two primary bronchi. The trachea occupies the median sagittal plane of the chest, and remains in front of the esophagus (Figs. 300, 310, 311). The caliber and structure of the thoracic trachea are similar to those of the cervical part (p. 182). At the margins of the

primary bronchi a sagittal spur, the *carina*, which is seen clearly through the bronchoscope, runs upward into the lumen. The right bronchus continues nearly in the direction of the trachea, but the left is placed more horizontally. For this reason foreign bodies are much more likely to drop into the right bronchus.

THORACIC ESOPHAGUS. The thoracic esophagus is the continuation of the cervical esophagus and follows a somewhat curved course. It reaches the esophageal orifice of the diaphragm at the level of the tenth thoracic vertebra.

The *length* of the adult esophagus is 25 cm. (Fig. 320). An important measurement in esophageal manipulations is the distance from the teeth to the cardia. This is derived by adding the distance from the incisor teeth to the beginning of the esophagus at the cricoid cartilage, a distance of 15 cm., giving a total of 40 cm. All measurements must be made carefully, since they may demonstrate accurately the site of tumors and strictures.

The esophagus presents three distinct *narrowings*. The first is at its beginning at the level of the cricoid cartilage. The second is behind the bifurcation of the trachea (broncho-aortic constriction) at the level of the fourth thoracic vertebra. The third constriction is at its point of passage through the esophageal hiatus into the abdominal cavity (Fig. 320). These constrictions, particularly the second, have a tendency to stop foreign bodies, are subjected to maximum injury when chemicals are ingested, and are sites for carcinoma.

BRONCHIAL ARTERIES. The bronchial arteries take origin, with but few exceptions, from the superior portion of the thoracic aorta and the aortic arch, either directly or in common with intercostal arteries (Fig. 321); when, in rare instances, the origin is subclavian, the bronchial artery so derived is supplementary to one or more bronchial vessels of aortic origin. In three-fourths of the cases examined in the senior author's laboratory the bronchial arteries arise independently of each other; in the remaining fourth of the cases as many as three may spring from a common stem. Topographically, bronchial arteries arise most frequently from the aorta in the segment opposite the

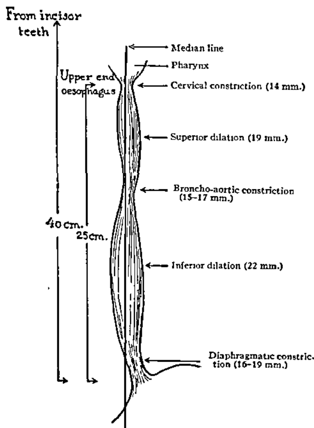


Fig. 320. THE ESOPHAGUS FROM THE FRONT, TO SHOW ITS DILATIONS, CONSTRICTIONS AND MEASUREMENTS.

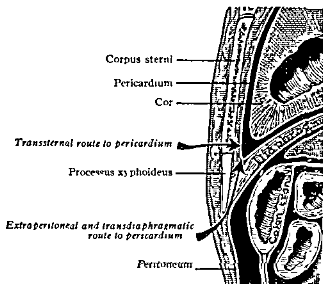


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sixth thoracic vertebra. Origins occur cranially, however, as far as the third thoracic vertebra, and caudally to the horizontal level of the eighth thoracic.

The bronchial arteries, although exhibiting variation in pattern, may be described on the basis of types. The most commonly encountered schema of bronchial arterial supply, type I, occurred in 40.6 per cent of specimens of 300 cases (Fig. 322). In these specimens two left and one right bronchial artery are present. Next in the order of frequency is the pattern of type II, in which a single bronchial artery passes to each lung; this schema of bronchial arterial origin occurred in 21.3 per cent of cases. The third major group, type III, is characterized by bilateral duplication of the arteries; it was encountered in 20.6 per cent of cases. These three types comprised 82.5 per cent of the arterial patterns in all cadavers studied (that is, together they represent approximately seven of eight specimens). In 9.7 per cent of cases, type IV, the pattern was found to be the reverse of type I—with one artery to the left lung and two to the right. In type V, three arteries were sent to the left lung, a single vessel to the right; this schema of bronchial supply occurred in 4 per cent of specimens. In 2 per cent of specimens, type VI, three bronchial arteries were present on the left side, two on the right. In two cases, type VII, 0.6 per cent, the reverse of this pattern was encountered (three on the right, two on the left). In two specimens, type VIII, 0.6 per cent, four bronchial arteries were present on the left side. In another, type IX, 0.6 per cent, the pattern was the reverse of that representing type VIII.

Most frequently there were three bronchial arteries, two left and one right. In some specimens, however, there were two right bronchial arteries; in such cases the second right bronchial artery coursed either ventral or dorsal to the esophagus. The bronchial artery of the ventral surface of the esophagus usually passed anterior to the bifurcation of the trachea, ultimately reaching the inferior border of the right main bronchus.

It has been determined that the circulation to the lungs is not as simplified as some of the current concepts would indicate. Connections which may exist between the various vessels have been described and figured by Dr. Charles E. Tobin. Among the connections are short or long anastomoses between the bronchial and pulmonary arteries (Fig. 323, at 6 and 7). Shunts larger than capillaries are found between the branches of the pulmonary artery and the pulmonary veins (Fig. 323 at 3), which may shunt blood away from a part not requiring a large circulation, or reduce the pressure should systemic pressure from enlarged bronchial arteries or a patent ductus arteriosus have conveyed blood to the particular area. The

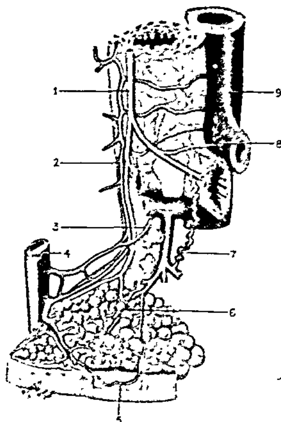


Fig. 323. CONNECTIONS BETWEEN THE BLOOD VESSELS IN A SMALLER SUBDIVISION OF THE LUNG. (MODIFIED FROM BRAUS; DIAGRAMMATIC).

1, Bronchial artery; 2, bronchial vein; 3, shunt between a branch of the pulmonary artery and a branch of the pulmonary vein; 4, intersegmental position of the pulmonary vein; 5, shunt in the pleura between branches of the pulmonary artery and pulmonary vein; 6, anastomosis between branches of the bronchial and pulmonary arteries in a lobule of the lung; 7, longer, coiled anastomotic channel between branches of the bronchial and pulmonary arteries at the apex of the lobule; 8, branch of the bronchial artery forming the vasa vasorum of the pulmonary artery; 9, a larger branch of the pulmonary artery coursing parallel to, and subdividing with, the branches of the bronchus. Also note a branch of the bronchial artery to the visceral pleura between adjacent segments (or lobules) at the lower left side of the diagram. (From Tobin: Surg., Gynec. & Obst., 95: 741-50, 1952.)

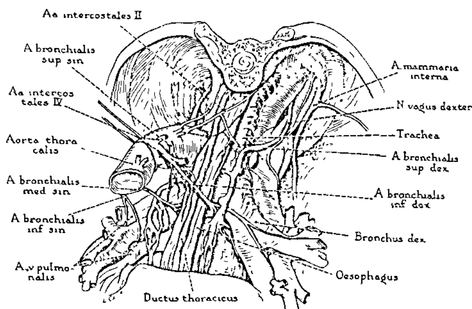


Fig. 321. BRONCHIAL ARTERIES AND RELATED STRUCTURES IN THE POSTERIOR MEDIASTINUM.

The thoracic aorta has been transsected and drawn to the left side; the azygos vein has been removed. It is demonstrated that the bronchial arteries arise in series with the aortic intercostals, and follow the bronchi in their inferolateral descent (From Cauldwell, Siekert, Lininger and Anson: Surg., Gynec. & Obst., 86: 395-411, 1948.)

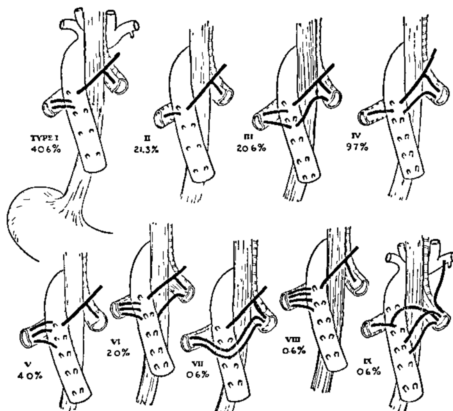


Fig. 322. TYPES OF BRONCHIAL ARTERIAL SUPPLY IN 300 SPECIMENS, SHOWN SCHEMATICALLY AS IF SEEN FROM THE DORSAL ASPECT.

The classification is based upon origin, number and course of the vessels. (From Cauldwell, Siekert, Lininger and Anson: Surg., Gynec. & Obst., 86: 395-411, 1948.)

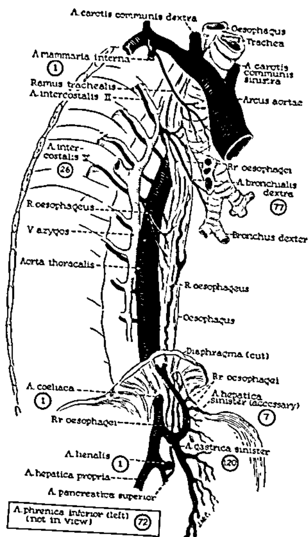


Fig. 325. ESOPHAGEAL AND BRONCHIAL ARTERIES, VIEWED FROM THE RIGHT AND IN FRONT; SEMISCHEMATIC. The encircled numbers near the labelled vessels record the frequency of origin of esophageal rami from the particular source in 125 specimens. (From Swigart, Siekert, Hambley and Anson: Surg., Gynec. & Obst., 90: 234–43, 1950.)

arose from the ascending segment descended a greater distance on the esophagus than did those vessels arising from the other two segments. Esophageal branches arose approximately as frequently from the ascending segment of the inferior thyroid artery as from the descending segment.

For the thoracic portion of the esophagus, the left inferior bronchial artery gave rise to esophageal vessels more frequently than did the other bronchial arteries (Figs. 325, 326). Vessels of such origin descended on the esophagus and anastomosed with the first (proximal) esophageal artery of aortic origin in many instances. The superior right bronchial artery was the second most common bronchial source of esophageal arteries. The latter vessels usually ascended on the esophagus, and a definite anastomosis with an esophageal branch of cervical origin could frequently be demonstrated. Although in some specimens no esophageal arteries arose directly from the thoracic aorta, in others one or two such arteries took origin from the thoracic portion of the aorta. In no specimen were there as many as four or five segmental branches derived from the aorta—contrary to statements made in textbooks of anatomy. The majority of vessels of segmental supply from the aorta occurred between the level of the seventh and ninth ribs or interspace, inclusive. Such intercostal arteries were the source of origin of esophageal arteries in one fifth of the specimens studied; usually, one esophageal vessel originated from an intercostal

plexus of venous channels which surround the bronchi (Fig. 323 at 2) drains into the pulmonary veins or, by anastomoses along the course of the bronchus, may drain into the azygos system. The pleura may be supplied by direct branches derived from bronchial arteries (particularly along the intersegmental or interlobar fibrous septa) or by branches of the pulmonary artery which anastomose with the bronchial artery (Fig. 323, at 6). Arteriovenous shunts may be present in the pleura (Fig. 323, at 5).

In a study of 150 specimens it was found that for the cervical portion of the esophagus, arteries originate from three segments of the inferior thyroid arteries. In the majority of cases one esophageal artery arose from a segment, although one or two segments of the thyroid artery might give rise to an esophageal branch (Fig. 324). Esophageal vessels arose from the terminal branches of the inferior thyroid artery more frequently (although small in caliber) than did similar vessels from the ascending and descending segments of the inferior thyroid artery. Those vessels which

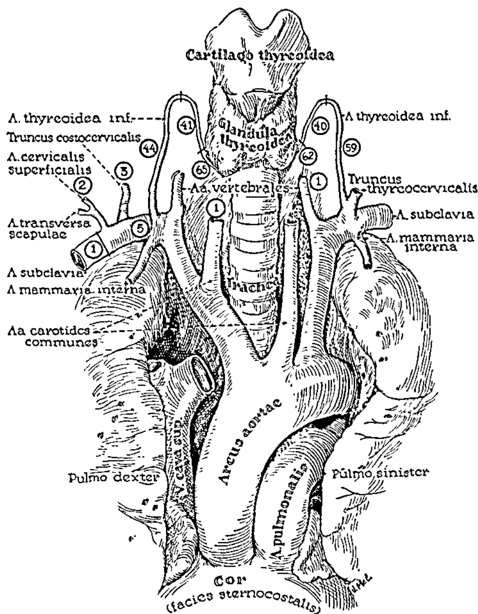


Fig. 324. ESOPHAGEAL ARTERIES OF CERVICAL ORIGIN, SEMISCHEMATIC.

The perpendicular lines which transsect each of the inferior thyroid arteries indicate the divisions of the vessel into ascending, descending and terminal segments. The encircled numeral placed either near or on a vessel records the number of instances in 100 specimens studied in which esophageal rami originate from the particular vessel. (From Swigart, Siekert, Hambley and Anson: Surg., Gynec. & Obst., 90: 234–43, 1950.)

descend, those of caudal origin ascend, in passing from the intercostal spaces toward the midline (Fig. 327).

Gangliated Sympathetic Chain. The gangliated sympathetic chain is the most laterally placed structure in the posterior mediastinum (Fig. 327). It lies upon the heads of the ribs and is overlaid by the costal pleura and the intercostal vessels. The thoracic portion of the chain contains ten or eleven ganglia, of which the first and largest lies on the neck of the first rib or may be fused with the inferior cervical ganglion (p. 204). A characteristic of the thoracic ganglia is the almost unvarying connection each has with the thoracic spinal nerves through the rami communicantes.

Branches from the chain run to the subclavian vessels and the heart, contributing to the formation of the pulmonary and aortic sympathetic plexuses. From the lower part of the cord, the *splanchnic trunks* are given off and are distributed to the structures in the abdominal cavity. Between the fifth and ninth ganglia arises the *major splanchnic nerve*, which is of

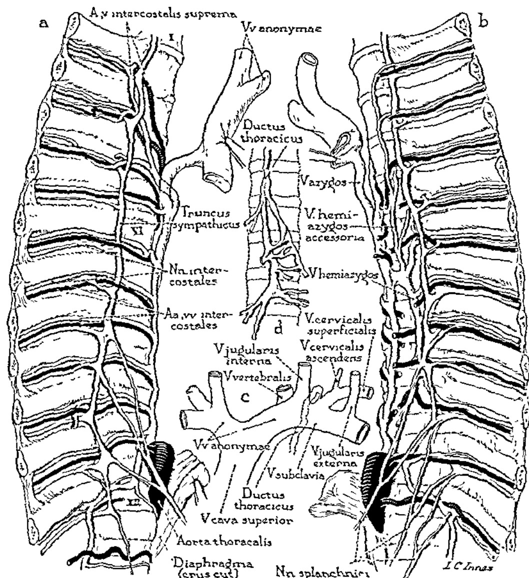


Fig. 327. AZYGOS SYSTEM OF VEINS, INTERCOSTAL VESSELS AND NERVES, THORACIC DUCT AND RELATED STRUCTURES.

a and *b*, Prevertebral region, showing the blood vessels and nerves; anterolateral views, *from* the *right* and left sides, respectively. *c*, Innominate veins, their chief tributaries, and the point of termination of the thoracic duct. *d*, Thoracic duct and cisterna chyli at upper lumbar level. A case in which the lymphatic tributaries were anastomotic, but *not* sacculated.

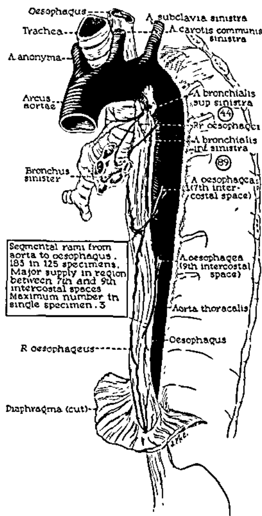


Fig. 326. ESOPHAGEAL AND BRONCHIAL ARTERIES, VIEWED FROM THE LEFT AND IN FRONT; SEMI-SCHEMATIC.

The encircled numbers represent the frequency with which esophageal rami arose from the particular bronchial artery in 125 dissections. (From Swigart, Siekert, Hambley and Anson: Surg., Gynec. & Obst., 90: 234–43, 1950.)

artery. The fifth right intercostal artery gave rise to esophageal arteries more frequently than did the other intercostal arteries.

To the abdominal portion of the esophagus, the left gastric artery gave rise to esophageal arteries in all but eight specimens. Esophageal arteries in five of the eight cases arose from the accessory left hepatic artery. In approximately three fourths of the specimens one to three esophageal arteries originated from the left gastric artery. In slightly less than one half of the cases the left inferior phrenic artery gave supply to the esophagus, there usually being a single esophageal branch from this source. An esophageal artery originated from the right inferior phrenic artery in only five specimens.

DESCENDING PART OF THE THORACIC AORTA. The descending part of the thoracic aorta extends from the termination of the arch at the inferior left side of the fourth thoracic vertebra to its diaphragmatic orifice. In the superior portion of its course the aorta deviates a little to the left of the median line, but gradually regains the median plane to enter the abdomen through the aortic hiatus (p. 290). The intimate relation of the aorta with the pleura and the left lung explains the rupture of aortic aneurysm into the pleural sac (Fig. 287).

THORACIC DUCT. The thoracic duct is the left main collecting vessel of the lymphatic system, and is far larger than the other terminal, the right lymphatic duct. The thoracic duct begins in the epigastric region at the height of the first and second lumbar vertebrae as an elongated dilation, the *cisterna chyli*, into which the right and left lumbar lymphatic trunks empty (Fig. 327). From the cistern the duct runs upward along the right side of the aorta, traversing the aortic hiatus. It crosses the median plane from right to left and ascends to the root of the neck, where it empties into the left innominate vein at the angle of union of the left internal jugular and subclavian veins (Fig. 327). The duct is provided with valves, the most perfect and important of which are at its termination to prevent the passing of blood into the duct.

AZYGOS SYSTEM OF VEINS. The azygos vein and its main tributary, the hemiazygos, arise in the abdomen as continuations of the ascending lumbar veins and penetrate the chest, the azygos on the right and the hemiazygos on the left (Fig. 327). They form a system of two parallel veins flanking the vertebral column, which on either side absorb the intercostal, esophageal and bronchial venous flow. They join at about the level of the seventh thoracic vertebra. The main trunk opens into the posterior surface of the superior vena cava at a point above the level at which the vessel is invested by pericardium (Fig. 287).

The tributary veins in the intercostal portion of their course lie cranial to the corresponding arteries; with rare exceptions the nerve is the most caudally placed member of the triad. Regularly the veins lie posterior, or deep to, the thoracic sympathetic trunk. In general, it may be said that only the intercostal veins of the middle set follow a transverse course across the vertebral bodies to their azygos terminations; those of cranial position

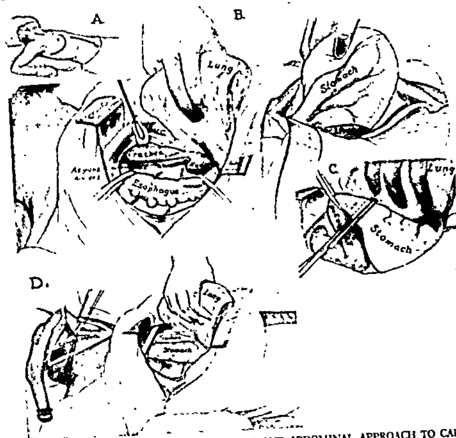


Fig. 329. THE COMBINED CERVICAL, RIGHT THORACIC AND ABDOMINAL APPROACH TO CARCINOMA OF THE UPPER THORACIC ESOPHAGUS.

A, Position on table with sites of incisions used. *B*, Esophagus and tumor mobilized by thoracic operator while stomach is freed by abdominal team. *C*, Mobilized stomach delivered into right hemothorax before division of esophagogastric junction. *D*, Cervical esophagus exposed through incision in the right side of neck, and gastric fundus drawn up for anastomosis to esophagus just below the pharynx. Abdominal wound is closed by part of the team while the anastomosis is in progress. (From Conerly, Jr., Carlson and Scott, Jr.: Surg., Gynec. & Obst., 98: 1-7, 1954)

first with a mirror and then with the laryngoscope; the trachea and bronchi should be viewed by means of the bronchoscope for further information. Difficulty in swallowing (dysphagia) may be caused by a foreign body in the esophagus. An esophageal foreign body occasionally produces marked dyspnea not relieved by tracheotomy. Accurate search demands esophagoscopy. A large body impossible of withdrawal through the esophagoscope requires esophagotomy.

RIGHT THORACIC APPROACH TO THE ESOPHAGUS. Since the report of Lewis* in 1946 stating the advantages of an approach to malignant tumors of the upper esophagus from the right side of the thorax, considerable clinical evidence has accumulated to support this view. The azygos vein is the only structure which impedes exposure of the esophagus on the right (Fig. 287), and this can be divided, while the arch of the aorta presents a major obstacle on the left (Fig. 286).

For anastomosis after resection of a lesion of the esophagus even in its upper fourth, the stomach (Figs. 329, 336, 337) or colon (Fig. 342) can be brought upward through the left thorax, even into the neck.

A technique of esophageal resection and anastomosis through a cervical, right thoracic and abdominal incision permits direct vision for the upper thoracic surgery and facilitates gastric mobilization (Fig. 329; *cf.* Fig. 331).

ESOPHAGEAL STRICTURE. Stricture or stenosis, the commonest esophageal affection, results from a variety of causes. Corrosive stricture in children, caused by drinking chemicals such as lye, is appallingly frequent. Intrinsic stricture fairly often is caused by squamous-cell epithelioma, the type of neoplasm almost invariably found in the esoph-

* Brit. J. Surg., 34: 18-31, 1946.

considerable size (Fig. 327). It descends through the posterior mediastinum, runs through the diaphragm, and joins the celiac ganglion. From the ninth and tenth ganglia the *minor splanchnic nerve* descends to join the celiac ganglion plexus (*aorticorenal ganglion*).

Surgical Considerations

METHODS OF ESOPHAGEAL EXAMINATION. The most useful adjuncts to clinical examination of the esophagus are the esophagoscope and the x-ray. The esophagoscope is of the greatest value. By its use alone, early diagnosis may be made and local treatment, such as dilation, removal of foreign bodies and excision of tissue specimens, may be performed. The examining tube is passed slowly and gently along the esophagus. The procedure requires knowledge of the region, dexterity, gentleness and absolute control of the patient. Through the instrument, the esophagus is seen to unroll, and, if normal, the passage is visible down to the cardia. In trained hands the procedure can be accomplished under local anesthesia in a few minutes.

MEGAESOPHAGUS. This is a common disease characterized by dysphagia and abnormal dilatation of the esophagus. The entity is not understood from the standpoint of etiology, although changes in the myenteric plexus and disturbances in the nerve-muscle relationship have been claimed. Certainly there is a pathologic contraction of the circular muscle in the cardiac esophagus and proximal dilatation of the organ. Impairment of the patient's nutritional status is a common feature and seems proportional to the severity of the primary disease. The Heineke-Mikulicz procedure of widening the esophagogastric junction has not been satisfactory because of the frequent complication of gastritis and reflex esophagitis. Excellent results have been claimed with the transthoracic linear myotomy (Fig. 328). A transthoracic approach is selected in order to be able to divide the hypertrophic muscular layers of the esophagus for 8 to 12 cm. cranialward from the esophagogastric junction.

FOREIGN BODIES IN THE ESOPHAGUS. A great variety of foreign bodies become impacted in the esophagus, usually above the bronchoaortic constriction (p. 333). Among the most common of these are false teeth, fish bones, pins, and pieces of wood. The foreign body may burrow into the mucous membrane, form a diverticulum, and embed itself, setting up infection and possibly abscess which may rupture into the pleura, pericardial cavity, a neighboring vascular trunk or even the aorta. A large bolus of food may engage behind the epiglottis, completely closing the laryngeal cavity. Cough or difficulty in breathing (*dyspnea*) suggests a foreign body in the air passages. A foreign body in the larynx or bronchi may be diagnosed as asthma. If the obstruction is in the inferior trachea, dyspnea will not be relieved by tracheotomy. The larynx should be examined

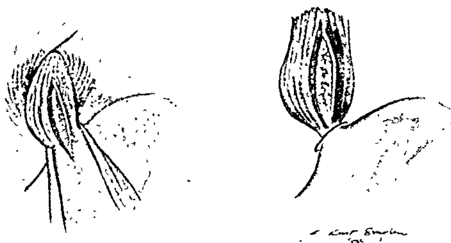


Fig. 328. LINEAR MYOTOMY FOR MEGAESOPHAGUS.

Through a transthoracic approach the hypertrophic and gritty muscular coat of the lower 8 to 12 cm. of the esophagus is incised to expose the underlying mucosa, which bulges into the incision in much the same manner as the pyloric mucosa during a Fredet-Ramstedt procedure. Care must be taken not to leave an intact band of muscle at the junction of the esophagus and stomach. (From Effler and Rogers: Arch. Surg., 71: 551–9, 1955.)

the most frequently encountered malformation of the esophagus, and several different types (Fig. 330) may be recognized by roentgenologic observation after injection of a small amount of Lipiodol into the proximal esophageal segment.

If the condition is recognized promptly after birth, before serious infection of the lungs has developed, it may be possible by surgical intervention to close the fistula opening in the trachea and to perform a primary anastomosis between the upper and lower segments of the esophagus. The first successful case, done through a posterior approach, was reported in 1943 (Fig. 331), and the number of children treated is steadily increasing.

An approach through the right fifth interspace with transection of several adjacent ribs posteriorly also allows a fair exposure.

Approach to the Thoracic Sympathetic Chain. The upper thoracic sympathetic chain is resected for the treatment of Raynaud's disease and other allied conditions, such as causalgia, traumatic arthritis and amputation stump pain. A supraclavicular or upper anterior thoracic approach may be used, but access posteriorly is preferred by many surgeons (Fig. 332).

One procedure in the surgical treatment of hypertension entails an extensive thoracolumbar sympathectomy. This covers a long area, but one approach permits removal of the

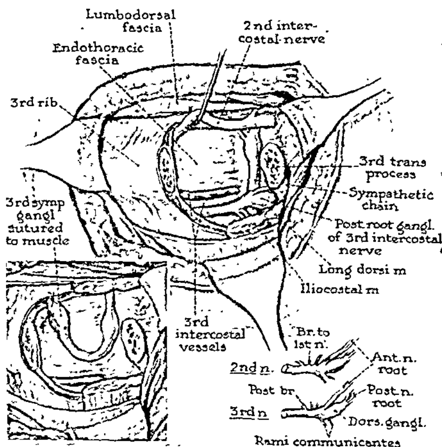


Fig. 332. POSTERIOR APPROACH TO THE UPPER THORACIC SYMPATHETICS.

The skin incision starts slightly below and lateral to the spinous processes of the seventh cervical vertebra, and runs parallel to the medial border of the abducted scapula. The trapezius is split in the direction of its fibers. The rhomboid major and minor muscles are retracted, and the lumbodorsal fascia split transversely. The third rib is resected paravertebrally for 6 cm. and the transverse processes removed. The pleura and endothoracic fascia are peeled off the vertebral bodies. The second and third intercostal nerves are gently developed and sectioned proximal to the posterior root ganglion intradurally. A small segment of the nerves is excised. The sympathetic chain is cut below the third dorsal ganglion and sutured to muscles. Method of Smithwick. (From DeTakats: *Surg., Gynec. & Obst., 79: 359–67, 1944.*)

agus. Syphilis may cause a widespread stenosis.

Esophagoscopy must not be delayed, lest a tumor in the wall of the esophagus be overlooked until too late for resection. Obstructive extrinsic stenosis from the pressure of enlarged mediastinal glands, malignant disease in the mediastinum, aortic aneurysm or spinal abscess is not uncommon.

When esophagoscopic examination has ruled out ulcerative conditions and the stricture is known to be benign, the treatment is mechanical dilation under direct vision through the esophagoscope. The blind use of bougies in the esophagus is obsolete, even in the hands of the most expert. Should the obstruction be so severe as to interfere with general nutrition, gastrostomy must be considered. The operation, if performed when the patient is in a fair state of nutrition, and under local anesthesia, is neither dangerous nor difficult.

Congenital Atresia of the Esophagus with Tracheo-esophageal Fistula. This is

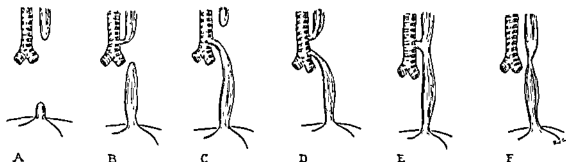


Fig. 330. TYPES OF CONGENITAL ABNORMALITIES OF THE ESOPHAGUS.

A, Esophageal atresia with no communication with the trachea. In such cases the lower end of the esophagus is usually short. *B*, Atresia with communication between the upper esophageal segment and the trachea. *C*, Esophageal atresia with communication retained between the lower segment and the trachea (on the latter's dorsal aspect). *D*, Atresia of a type in which discontinuous segments of the esophagus communicate separately with the trachea. *E*, Esophagus with no disruption of continuity, but with tracheo-esophageal fistula. *F*, Esophageal stenosis. (From Gross: The Surgery of Infancy and Childhood.)

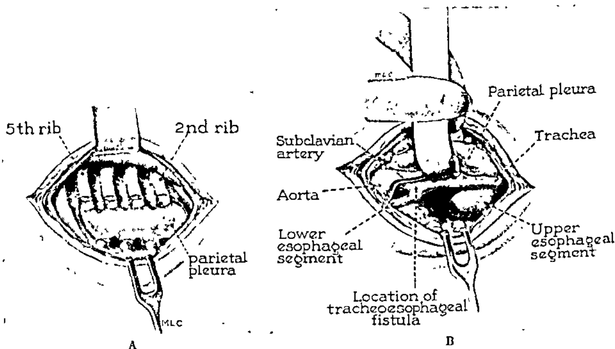


Fig. 331. POSTERIOR APPROACH USED IN FIRST SUCCESSFULLY TREATED CASE OF CONGENITAL ATRESIA OF THE ESOPHAGUS WITH TRACHEO-ESOPHAGEAL FISTULA.

A, Extent of costal resection. *B*, Diagram of the extrapleural exposure of the anomaly. (From Haight and Towsley: Surg., Gynec. & Obst., 76: 672–88, 1943.)

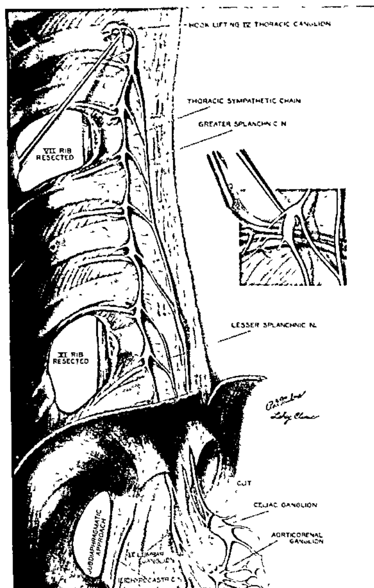


Fig. 334. INSIDE VISUALIZATION OF RIGHT THORACOLUMBAR SYMPATHETIC SYSTEM IN RELATION TO OPERATIVE APERTURES.

Removal of the entire chain in one piece from the fourth thoracic through the third lumbar ganglia with the greater and lesser splanchnic nerves can be accomplished. Ten days later the opposite side is done. Insert shows the separation of a ganglion from the intercostal vessels before the rami communicantes are divided. (From Poppen: Surg., Gynec. & Obst., 84: 1117-23, 1947.)

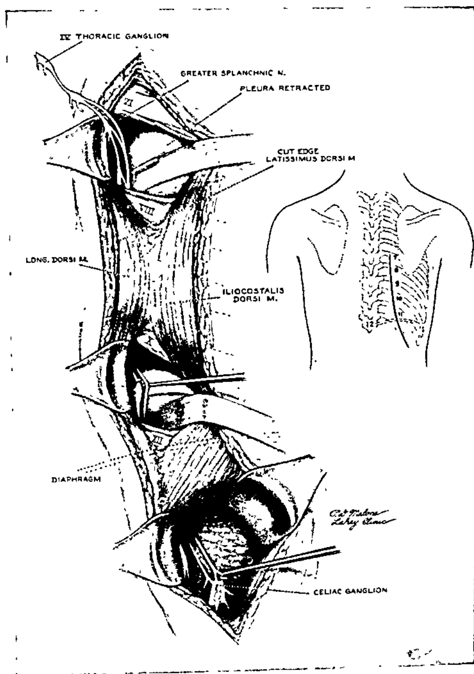


Fig. 333. INCISION FOR EXTENSIVE COMBINED THORACOLUMBAR SYMPATHECTOMY.

The thoracic chain and its branches are reached behind the pleura by separating the iliocostalis and longissimus dorsi muscles and then removing posterior segments of the seventh or eighth and eleventh ribs. Below the twelfth rib the sacrospinalis muscles of the back are retracted toward the spinous processes, the lumbodorsal fascia and the transversalis fascia are incised, and the retroperitoneal space entered. (From Poppen: Surg., Gynec. & Obst., 84: 1117–23, 1947.)

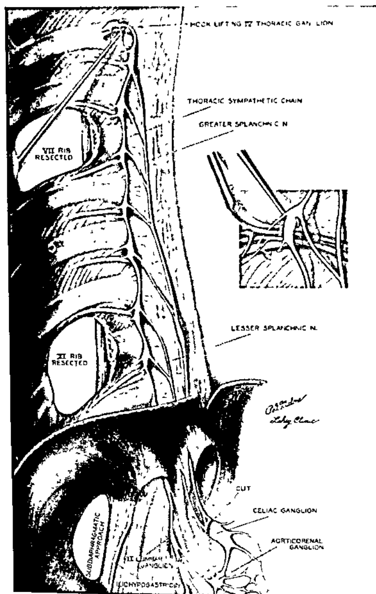


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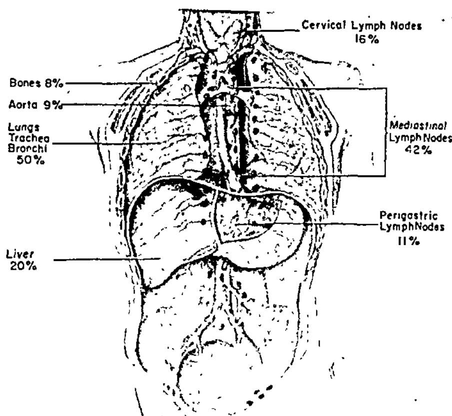


Fig. 335. THE SPREAD OF CARCINOMA OF THE ESOPHAGUS.

Diagrammatic sketch illustrating the relative frequency with which various organs and lymph node areas are involved in secondary deposits from carcinoma of the esophagus. Figures are based on 185 postmortem examinations. (From Watson and Goodner: Am. J. Surg., 93: 259-65, 1957.)

sympathetic system from the fourth thoracic to the third lumbar ganglion, inclusive (Figs. 333, 334).

CARCINOMA OF THE ESOPHAGUS. *Primary* carcinoma of the esophagus is a squamous-cell growth arising from the epithelium of the mucous membrane. By annular invasion of the esophageal wall the growth gradually obliterates the lumen and then ulcerates. When first diagnosed, the lesion is generally in a late stage with spread to near and distant lymph nodes and to other organs (Fig. 341). The contiguous tissues are vital structures—trachea, aorta, and so on (Figs. 286, 287)—not easily resected en masse. The carcinoma itself produces few symptoms until large enough to cause obstruction, and spreads for a considerable distance up and down in the submucosa. With rare exception, it is not curable by any of the methods available at present. Accordingly, relief should be directed towards palliative management.

The earliest symptom of trouble is difficulty in swallowing. When the lumen becomes seriously encroached upon, there is intense dysphagia with the feeling of a foreign body in the throat, because of the arrest of food. Progressive emaciation is an early characteristic of the disease, succeeded by *inanition* and exhaustion. Early cases can be recognized only by esophagoscopy and x-ray examination. In carcinoma of the esophagus, dilating instruments passed blindly are weapons *rather than* tools.

PATHS OF APPROACH TO THE ESOPHAGUS. Recent years have seen a great increase in the number of operations upon the esophagus, usually for carcinoma, and occasionally for cicatricial obliteration or congenital anomalies.

Early, favorable tumors of the cervical esophagus can be resected through the neck (p. 199) and continuity restored by developing a skin-lined tube. The thoracic esophagus can be completely approached and resected by lengthy removal of the left eighth rib (Figs. 291, 292) and division of one or more ribs posteriorly to allow wider retraction. Alimentary tract continuity is then restored by freeing the stomach or colon, entailing ligation of many of their vessels (Figs. 336, 342), and by bring-

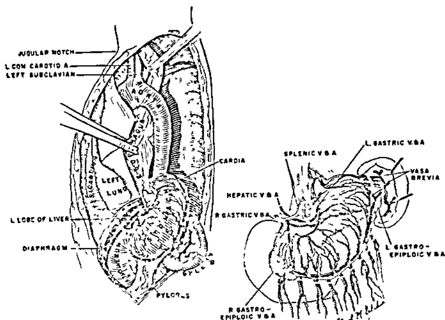


Fig. 336. RESECTION OF THORACIC ESOPHAGUS.

Diagram to show the amount of dissection necessary to remove the entire thoracic portion of the esophagus and to free the stomach sufficiently to perform a high intrathoracic esophagogastric anastomosis at the apex of the chest. Inset shows the principal blood vessels of the stomach divided in the freeing process. The only blood supply remaining, which is remarkably adequate, comes from the right gastric and right gastroepiploic arteries. (From Sweet: Surg., Gynec. & Obst., 83: 417–27, 1946.)

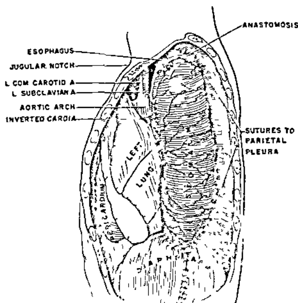


Fig. 337. ANASTOMOSIS AFTER RESECTION OF THORACIC ESOPHAGUS.

Diagram of anatomic relations after restoration of high esophagogastric continuity, and closure of diaphragm about the stomach. (From Sweet: Surg., Gynec. & Obst., 83: 417–27, 1946)

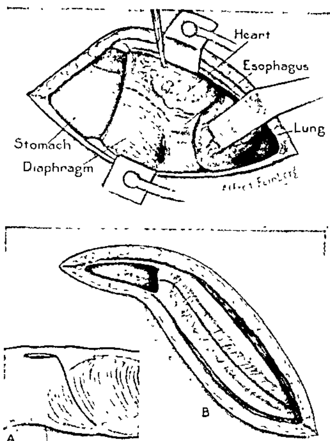


Fig. 338. GARLOCK COMBINED ABDOMINOTHORACIC APPROACH TO LOWER END OF ESOPHAGUS AND CARDIA OF STOMACH.

A 5-inch left pararectus incision begins just below the costal arch between the left eighth and ninth ribs. Exploration of the abdomen should then be made to determine the extent and fixation of the primary tumor and possible metastases. If an operable tumor is found, the incision is swung upward and outward in the eighth rib interspace as far as the vertebral border of the scapula. The costal arch is divided along the line of incision between the eighth and ninth ribs. (From Garlock: Surg., Gynec. & Obst., 83: 737-41, 1946.)

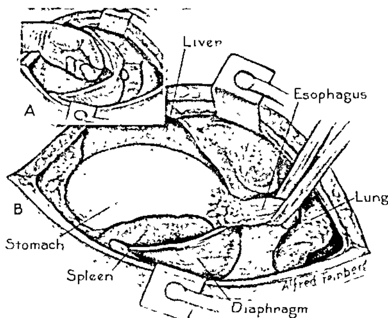


Fig. 339. GARLOCK COMBINED ABDOMINOTHORACIC INCISION (CONTINUED).

Diaphragm divided in direction of skin wound from its peripheral attachment to the esophageal hiatus. Rib edges retracted and excellent exposure of gastric cardia and lower esophagus obtained. (From Garlock: Surg., Gynec. & Obst., 83: 737-41, 1946.)

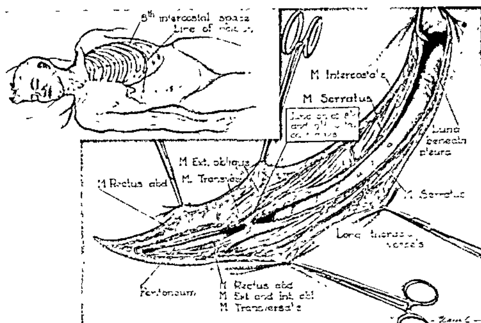


Fig. 340. CARTER COMBINED ABDOMINOTHORACIC APPROACH TO LOWER ESOPHAGUS AND UPPER ABDOMINAL ORGANS.

Inset diagrams the transverse incision in line with the eighth intercostal space from the midline to the midscapular line Muscles are divided as shown down to peritoneum and pleura. (From Carter: Surg., Gynec. & Obst., 84: 1019–29, 1947.)

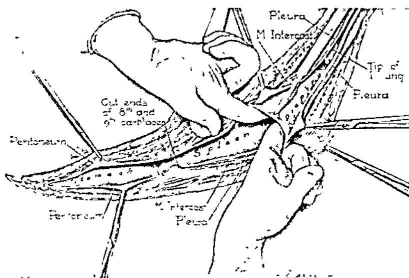


Fig. 341. CARTER INCISION (CONTINUED).

Peritoneum opened, costal cartilage divided, pleural cavity entered, and diaphragm incised. With a rib spreader a wide exposure of left lower thoracic and upper abdominal structures is obtained. (From Carter: Surg, Gynec. & Obst., 84: 1019–29, 1947.)

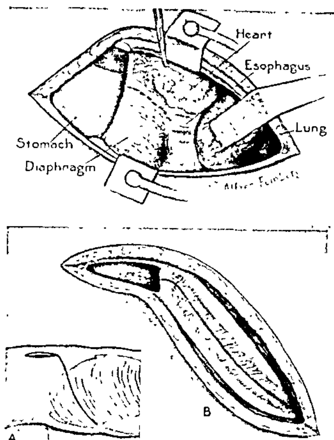


Fig. 338. GARLOCK COMBINED ABDOMINOTHORACIC APPROACH TO LOWER END OF ESOPHAGUS AND CARDIA OF STOMACH.

A 5-inch left pararectus incision begins just below the costal arch between the left eighth and ninth ribs. Exploration of the abdomen should then be made to determine the extent and fixation of the primary tumor and possible metastases. If an operable tumor is found, the incision is swung upward and outward in the eighth rib interspace as far as the vertebral border of the scapula. The costal arch is divided along the line of incision between the eighth and ninth ribs. (From Garlock: Surg., Gynec. & Obst., 83: 737-41, 1946.)

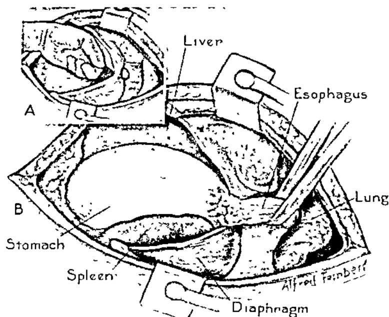
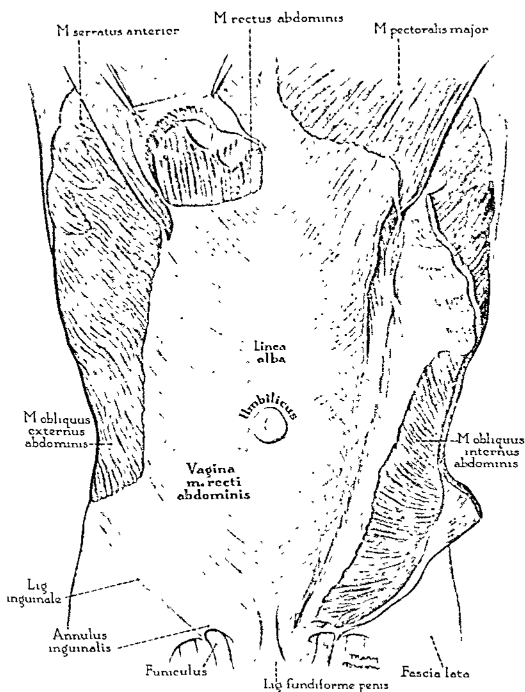


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Diaphragm divided in direction of skin wound from its peripheral attachment to the esophageal hiatus. Rib edges retracted and excellent exposure of gastric cardia and lower esophagus obtained. (From Garlock: Surg., Gynec. & Obst., 83: 737-41, 1946.)

PART IV

The Abdomen



ANTEROLATERAL ABDOMINAL MUSCULATURE

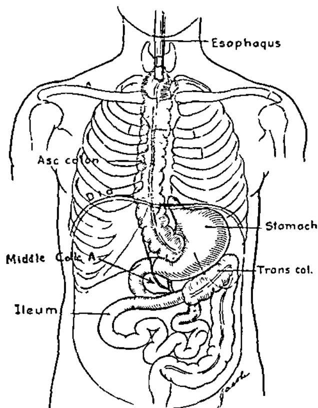


Fig. 342

ing the viscus up into the chest for anastomosis to the esophagus (Figs. 337, 342). Approach to the lower esophagus can be made through a thoracic incision or through a combined abdomino-thoracic incision (Figs. 338 to 341).

INTRATHORACIC TRANSPLANTATION OF THE RIGHT COLON FOR ESOPHAGEAL RECONSTRUCTION. In the search for a structure to restore alimentary tract continuity after resection of the esophagus, Sherman, Mahoney, Dale and Stabins* report their revival of an old method making use of the right colon with blood supply provided through the middle colic artery (Fig. 342).

* Cancer, 8: 1198–1205, 1955.

Fig. 342. USE OF THE RIGHT COLON AS REPLACEMENT FOR ESOPHAGUS.

The esophageal tumor is excised or, if this is impossible, the obstructed area is by-passed. The colon is mobilized and the transplant formed by dividing the right colic and ileocolic arteries, the terminal ileum and the transverse colon. The portion of the colon to be transplanted is now free except for its blood supply through the middle colic artery. (From Sherman, Mahoney, Dale and Stabins: Cancer, 8: 1198–1205, 1955.)

CHAPTER 14

Abdominal Wall

Anterolateral Wall in General

Definition and Boundaries. The anterolateral abdominal wall is bounded above by the flare of the costal margins and the xiphoid process of the sternum, and below by the iliac crests, inguinal ligaments, pubic crests and pubic symphysis. Its lateral margins are conventional vertical lines dropped from the costal margins to the most elevated portions of the iliac crests.

Surface Anatomy. The abdomen presents practical and reliable landmarks (Fig. 343). The *linea alba* extends in the midline from the xiphoid to the symphysis. It is divided by the *umbilicus* into supraumbilical and infraumbilical segments of about equal length. The *rectus muscles* form bulging bands on each side of the linea alba. Across them stretch the *lineae transversae*, tendinous intersections which, in more muscular persons, produce palpable transverse depressions. These depressions are accentuated in active rectus contraction or in reflex muscle spasm associated with irritation of the peritoneum.

At the lateral margin of each rectus muscle is a depression, the *linea semilunaris*, directed toward the symphysis. In thin subjects the *pubic spines* are palpable at the mesial attachments of the inguinal ligaments; in obese subjects they are lost in the depth of the pubic fat. Their location is determined accurately as two fingerbreadths superior to the suspensory ligament of the penis, about 2.5 cm. lateral to the midline.

For clinical purposes the anterolateral abdominal wall may be divided into nine regions by two vertical and two horizontal conventional lines. The *superior* of the *transverse lines* passes between the inferior margins of the costal

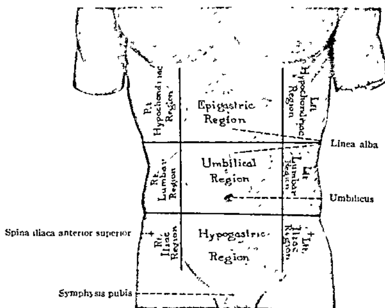


Fig. 343. REGIONAL TOPOGRAPHY OF THE ANTEROLATERAL ABDOMINAL WALL.

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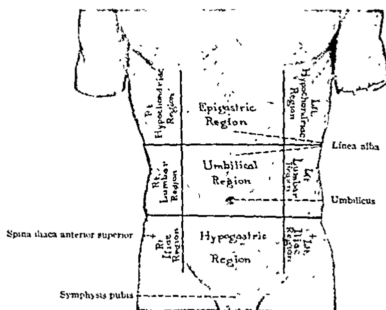


Fig. 343. REGIONAL TOPOGRAPHY OF THE ANTEROLATERAL ABDOMINAL WALL.

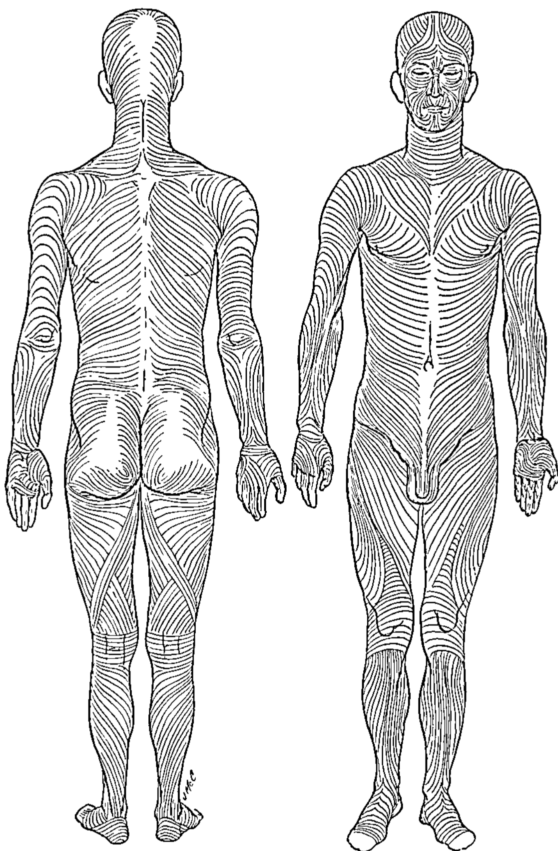


Fig. 344. LINES OF TENSION OF THE SKIN (LANGER).

The general course of the connective tissue bundles of the corium determines the direction of these linear clefts. Whenever possible, incisions should follow these lines, since there will then be little gaping of the wound and a subsequent fine scar. Broader scars follow incisions across the lines.

flares (tips of the tenth ribs); the *inferior line* passes between the highest points of the iliac crests. The two *vertical lines* (mid-Poupart) bisect the two inguinal ligaments. Supero-inferiorly, the central regions are the *epigastric, umbilical* and *pubic*, or *hypogastric;* the lateral regions are the *hypochondriac, lumbar* and *iliac* (Fig. 343). These regions facilitate the description of fixed viscera and of tumors.

The *contour* of the abdomen is subject to considerable variation. A greatly enlarged liver may cause undue prominence in the right hypochondriac and neighboring regions. Ovarian cysts or uterine tumors produce enlargement first in the lower abdomen above the pubes, which later extends superiorly. Common causes of generalized distention are ascites, paralytic ileus, mechanical bowel obstruction and advanced peritonitis.

Retraction may be as striking as distention. The abdominal cavity may be reduced to small dimensions, and the anterior wall be depressed sufficiently to merit the description "scaphoid or boat-shaped" abdomen. The condition is seen in emaciated persons, in certain forms of peritonitis and, to a less degree, in some varieties of meningitis.

A thick abdominal wall, whether from muscular development or abundance of fat, is an obstacle to palpation. A thin, flaccid abdominal wall greatly facilitates palpation. In certain cases peristaltic movements along distended loops of intestine may be seen.

SUPERFICIAL STRUCTURES. The *skin* of the abdomen is attached loosely to the subjacent structures except at the umbilicus, where it adheres firmly. Over the entire surface of the body lines of tension of the skin are produced by the course of fibrous tissue bundles in the corium. Attention to their direction is important in making surgical incisions (Fig. 344).

The *superficial fascia* of the lower abdomen can be divided readily into two strata. In the superficial layer (Camper's fascia) lies the bulk of subcutaneous fat. The deep layer (Scarpa's fascia) is denser, and is applied more closely to the abdominal muscles. The subcutaneous tissue is supplied with *arteries* from various sources which contribute freely anastomosing branches. The area above the umbilicus receives branches from the superior epigastric, musculophrenic and lower intercostal arteries. Below the umbilicus are three small branches from the femoral artery, the superficial epigastric, superficial circumflex iliac and superficial external pudendal arteries.

The superficial epigastric, circumflex iliac, and pudendal *veins* converge toward the saphenous opening in the groin to enter the femoral vein and become tributary to the inferior caval system. The superficial veins above the umbilicus empty into the superior vena cava by way of the internal mammary, intercostal and long thoracic veins. Both groups join freely with one another through the thoraco-epigastric vein, which ascends from the groin to the region of the axilla. The two systemic groups of veins communicate indirectly at the umbilicus with the portal vein by means of potential anastomoses with the para-umbilical vein (of Sappey), which passes from the left branch of the portal vein along the round ligament of the liver to the umbilicus.

When the portal circulation is obstructed, as in hepatic cirrhosis, these anastomoses act as safety valves, and a large amount of blood, by reversal of flow, finds its way into the superficial veins about the umbilicus. In consequence, these veins assume a varicose appearance, fancifully termed "caput Medusae."

Because of the ample anastomosis between the supraumbilical and infraumbilical veins of the caval system, a reversal of blood flow will be seen in superior or inferior caval obstruction, all the blood being borne toward the unobstructed cava.

The *lymphatics* are divided into two general groups: those arising in the supraumbilical region and draining to the thoracic group of axillary glands, and those arising in the infra-umbilical region and draining toward the superficial glands of the thigh. Lymph vessels from the liver course along the ligamentum teres to the umbilicus to communicate with the lymphatics of the anterior abdominal wall. Cancer of the umbilicus occurs secondary to cancer of the liver, and metastases may spread to the lymph nodes in the groin.

BROAD ABDOMINAL MUSCLES, TRANSVERSALIS FASCIA, AND PERITONEUM. The flat muscles of the abdomen and the recti are arranged to form an elastic contractile layer about the abdominal cavity, protecting its contents. They function as a constricting mechanism, and the pressure they exert helps to maintain the abdominal viscera in their proper relative positions. The peristaltic contractions of the hollow viscera are supplemented by the uni-

form pressure of the abdominal muscles, as is well demonstrated in micturition and defecation.

The movements of the abdominal muscles alternate with those of the diaphragm, and are to be regarded as promoting the expiratory movements of the chest. Normal expiration is largely a result of the elastic recoil of the lungs and chest wall. When, as in emphysema, the lungs to a large extent lose their elasticity, the abdominal muscles partially compensate for the loss. Action of the abdominal muscles diminishes the intrathoracic space by contracting the thoracic outlet and pushing up the diaphragm.

By increasing the pressure brought to bear upon the abdominal contents, abdominal muscular contraction may be forcible and lead to partial rupture of some of the muscle fibers, not an uncommon occurrence in the recti during parturition and other excessive muscular strains.

The muscles of the anterior abdominal wall help to approximate the lower thorax and the pelvis, acting in antagonism to the posterior spinal muscles. This is shown well in momentary loss of balance, when the tendency to fall backward is counteracted by the powerful effort the abdominal muscles exert in drawing the thoracic segment of the trunk anteriorly. This sometimes results in their partial rupture. The broad muscles cross each other, an arrangement designed to strengthen the abdominal wall and diminish the risk of hernial protrusions between separated muscle bundles. The external and internal oblique and transversus abdominis muscles form the encircling musculature, while the recti and pyramidales muscles are important in flexion and stabilization.

The most superficial of the FLAT MUSCLES, the descending or *external oblique*, lies on the lateral (p. 374) and anterior parts of the abdomen. That portion of the aponeurosis which forms the inguinal ligament is rolled posteriorly and superiorly on itself and forms a groove to hold the spermatic cord (Frontispiece, Part IV). The mesial portion of the folded-back ligament is the *lacunar ligament* (of Gimbernat), which is attached to the pubic crest. It has a free lateral crescentic margin which is related intimately to the femoral (crural) canal (Fig. 364). Above the anterior extremity of the inguinal ligament, the spermatic cord emerges through the aponeurosis of the external oblique at the *subcutaneous inguinal ring*.

The *internal oblique muscle* is immediately deep to the external oblique (Frontispiece, Part IV). It arises from the lateral half of the inguinal ligament, from the anterior two thirds of the iliac crest and from the lumbodorsal fascia, and runs superiorly, anteriorly and mesially. It has no free posterior margin. The uppermost fibers are inserted into the lower ribs and their cartilages; the intermediate fibers form an aponeurosis which, above the semicircular line (of Douglas), divides into two lamellae at the linea semilunaris (Figs. 345, 347, 350). The anterior lamella accompanies the external oblique aponeurosis to form the anterior rectus sheath. The posterior lamella is fused with the aponeurosis of the transversus abdominis to form the posterior rectus sheath. Below the semicircular line, the combined aponeuroses of the internal oblique, external oblique and transversus abdominis muscles make up the anterior rectus sheath. The lowermost fibers of the internal oblique muscle arch over the spermatic cord, where they blend with the corresponding fibers of the transversus abdominis muscle to form the *inguinal falx* or *conjoined tendon*.

The *transversus abdominis* forms the most deeply placed muscle layer and is the most important constrictor. It arises from the lumbodorsal fascia, the iliac crest, the lateral third of the inguinal ligament and the inner aspect of the lower six costal cartilages by slips which interdigitate with those of the diaphragm. The general direction of the fibers is toward the linea alba. Its aponeurosis runs posterior to the rectus abdominis muscle above the semicircular line, and anterior to it below (Figs. 345, 350). The lowermost fibers turn mesially downward and insert on the pubic crest as part of the inguinal falx.

The above descriptions apply to the typical case, from which, actually, there are numerous departures (Fig. 346).

The TRANSVERSALIS FASCIA covers the deep surface of the transversus abdominis muscle and lines the abdominal cavity, reinforcing unprotected areas. Below the semicircular line, where the posterior sheath of the rectus abdominis muscle is absent, the fascia is strong and is in immediate contact with the muscle. The fascia is attached below to the inner lip of the iliac crest, the outer half of the inguinal

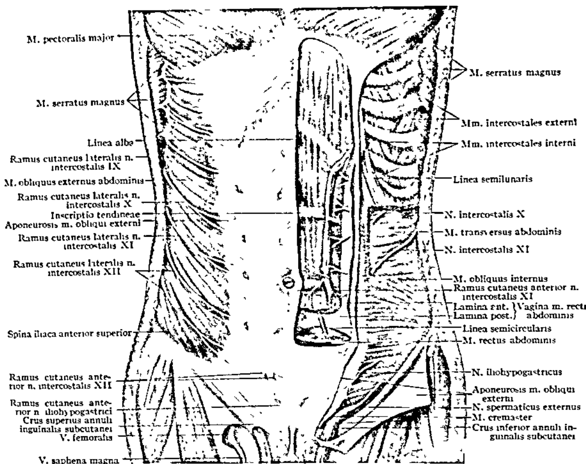


Fig. 345. MUSCLES OF THE ANTEROLATERAL ABDOMINAL WALL.

The anterior layer of the sheath of the left rectus is removed to show the rectus compartment and the mode of entrance of vessels and nerves; a section of the left rectus is removed to show the inferior epigastric artery; all the external oblique muscle and a window from the internal oblique muscle are removed on the left side to show the intercostal musculature and transverse abdominal muscle.

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Against the transversalis fascia, the PERITONEUM is applied closely; the two are separated by a layer of areolar tissue, the *extraperitoneal fat*, which is developed to an unusual degree about the inguinal ligament and is prone to descend with hernial sacs in this area. The peritoneum may be separated from the transversalis fascia with great ease save at the abdominal inguinal ring where fusion has taken place. In the inguinal region the peritoneum extends toward, but does not reach, the inguinal ligament, from which it is separated by an interval of fatty areolar tissue. In this tissue the inferior epigastric artery, or even the termination of the external iliac artery, may be ligated without invading the peritoneal cavity. An incision parallel with and a little superior to the inguinal ligament affords exposure for ligation of these vessels, as well as exposing the neck of a femoral hernial sac.

From the umbilicus three folds of peritoneum diverge downward, marking obliterated structures of fetal life (Fig. 368). The median fold sheaths the urachus, and the lateral folds contain the cordlike remnants of the obliterated umbilical arteries which continue in the direction of the superior vesicular arteries. A description of the peritoneal fossae delimited by these folds and their practical significance in inguinal hernia is given more appropriately with the inguino-abdominal region.

LINEA SEMILUNARIS. The lateral margin of each rectus abdominis muscle is indicated on the surface by a depression or vertically directed groove, the linea semilunaris. This line begins at the pubic tubercle and passes upward

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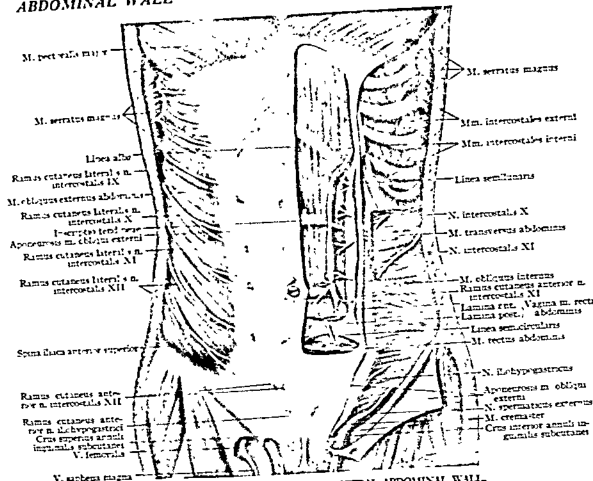


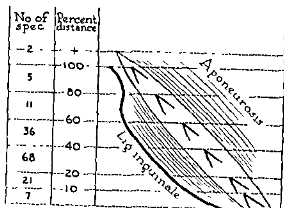
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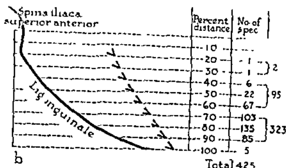
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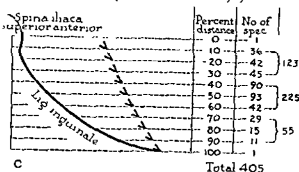


Fig. 346. VARIATIONS IN THE INGUINAL PORTION OF EACH OF THE ANTEROLATERAL ABDOMINAL MUSCLES; SHOWN SCHEMATICALLY, RECORDS FOR BOTH SIDES COMBINED TO APPEAR ON THE RIGHT.

a, In approximately 70 per cent of specimens (104 of 150) the superolateral extent of the intercrural fault in the aponeurosis of the external oblique layer lay caudal to the transverse level of the anterior superior spine of the ilium and that of the pubic symphysis. *b*, In 76 per cent of specimens (323 of 425) the muscle fibers of the internal oblique layer descended into the caudal third of the area bounded by the skeletal landmarks named in the description, preceding, of the external oblique layer. Beyond the caudal border of the fleshy portion, the layer was represented by fascia *c*, Muscle fascicles terminated at a more cranial level in the case of the transverse abdominal layer than in that of the internal oblique; in 53 per cent of cases (225 of 405) the area into which muscle fibers of the former layer descended was situated near the middle third of the area between the anterior superior spine of the ilium and the symphysis of the pubis. (From Morgan, McVay and Anson: Unpublished study.)

midway between the umbilicus and the anterior superior spine, toward the tip of the ninth costal cartilage. Along this line, above the linea semicircularis, the aponeurosis of the internal oblique muscle splits to enclose the rectus muscle (Figs. 345, 347, 350).

Rectus Abdominis Muscle and the Rectus Sheath. Each *rectus abdominis* (Frontispiece, Part IV; Figs. 347, 348, 350, 351) is a thick, flat band of muscle which arises from the anterior surface of the fifth, sixth and seventh costal cartilages and from the xiphoid process, and extends downward in the interval between the linea alba and linea semilunaris to an insertion on the pubis between the crest and symphysis. Three to five irregular tendinous intersections, lineae transversae, cross the muscle, adhering only to the anterior surface of the sheath. To some extent, they limit fluid collections beneath the anterior sheath and prevent muscle rupture. Their attachment to the anterior sheath prevents retraction of the rectus in transverse incisions. A transverse rectus wound, in healing, forms essentially a new fibrous intersection. The muscle is not attached to the posterior sheath and is freely movable over this surface, so that it may be retracted mesially.

The *sheath* of the *rectus* is a strong, incomplete fibrous compartment formed by the aponeuroses of the three lateral abdominal muscles which crisscross to make the linea alba. The composition of the sheath differs in its upper and lower portions. Above the midpoint between the umbilicus and the symphysis pubis, the rectus muscle has a well defined investment, formed in front by the aponeurosis of the external oblique and the anterior lamina of the aponeurosis of the internal oblique, and behind by the aponeurosis of the transversus abdominis and the aponeurosis of the posterior lamina of the internal oblique. The posterior wall is not entirely aponeurotic, for the upper fleshy fibers of the transversus abdominis muscle lie behind the rectus abdominis and almost reach the linea alba.

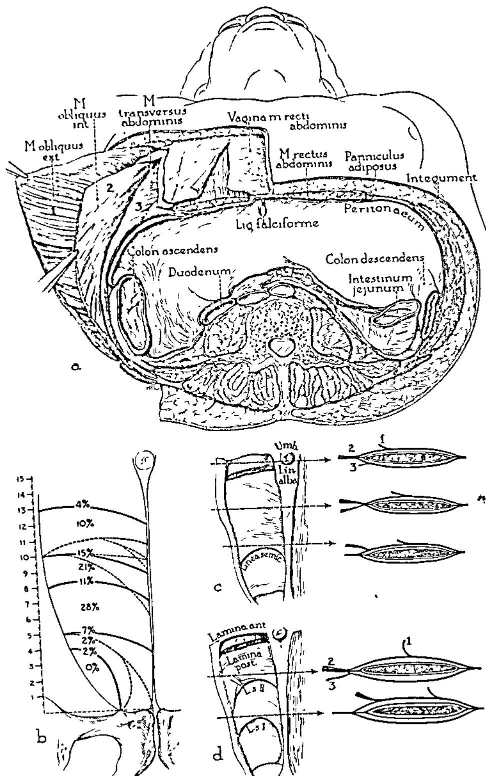
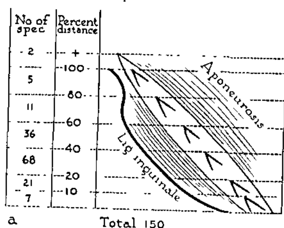
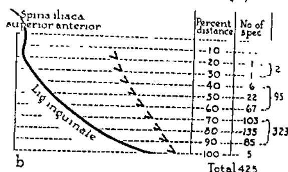


Fig. 347 RECTUS MUSCLE AND RECTUS SHEATH, WITH VARIATIONS IN FORMATION OF THE LATTER.
a, The abdominal and related deep muscles of the back, seen in a transverse section above the level of the umbilicus. *b*, Variation in position of the linea semicircularis in 56 parietal halves. Height in centimeters is recorded at the reader's left; percentage-occurrence is recorded midwidth of the sheath. The dotted lines represent cases in which lineae originate together laterally, but terminate medially at different craniocaudal positions. It is important to observe that in approximately 80 per cent of cases the semicircular line was situated in the middle third of the distance between the umbilicus and pubic symphysis. *c* and *d*, Variation in constitution of the rectus sheath (layers numbered as in *a*); anterior views and transverse sections. In *d*, primary and secondary lineae occur, owing to failure of aponeurotic fibers of internal oblique to pass totally in front of the rectus muscle at a single point (From McVay and Anson: Anat. Record, 77: 213-25, 1940.)





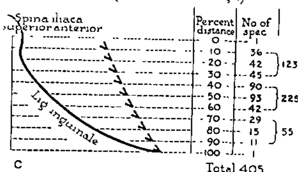


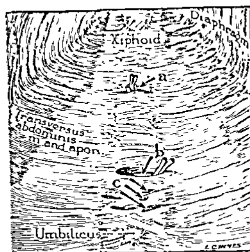
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a, In approximately 70 per cent of specimens (104 of 150) the superolateral extent of the intercrural fault in the aponeurosis of the external oblique layer lay caudal to the transverse level of the anterior superior spine of the ilium and that of the pubic symphysis. *b*, In 76 per cent of specimens (323 of 425) the muscle fibers of the internal oblique layer descended into the caudal third of the area bounded by the skeletal landmarks named in the description, preceding, of the external oblique layer. Beyond the caudal border of the fleshy portion, the layer was represented by fascia. *c*, Muscle fascicles terminated at a more cranial level in the case of the transverse abdominal layer than in that of the internal oblique; in 53 per cent of cases (225 of 405) the area into which muscle fibers of the former layer descended was situated near the middle third of the area between the anterior superior spine of the ilium and the symphysis of the pubis. (From Morgan, McVay and Anson: Unpublished study.)

midway between the umbilicus and the anterior superior spine, toward the tip of the ninth costal cartilage. Along this line, above the linea semicircularis, the aponeurosis of the internal oblique muscle splits to enclose the rectus muscle (Figs. 345, 347, 350).

Rectus Abdominis Muscle and the Rectus Sheath. Each *rectus abdominis* (Frontispiece, Part IV; Figs. 347, 348, 350, 351) is a thick, flat band of muscle which arises from the anterior surface of the fifth, sixth and seventh costal cartilages and from the xiphoid process, and extends downward in the interval between the linea alba and linea semilunaris to an insertion on the pubis between the crest and symphysis. Three to five irregular tendinous intersections, lineae transversae, cross the muscle, adhering only to the anterior surface of the sheath. To some extent, they limit fluid collections beneath the anterior sheath and prevent muscle rupture. Their attachment to the anterior sheath prevents retraction of the rectus in transverse incisions. A transverse rectus wound, in healing, forms essentially a new fibrous intersection. The muscle is not attached to the posterior sheath and is freely movable over this surface, so that it may be retracted mesially.

The *sheath* of the *rectus* is a strong, incomplete fibrous compartment formed by the aponeuroses of the three lateral abdominal muscles which crisscross to make the linea alba. The composition of the sheath differs in its upper and lower portions. Above the midpoint between the umbilicus and the symphysis pubis, the rectus muscle has a well defined investment, formed in front by the aponeurosis of the external oblique and the anterior lamina of the aponeurosis of the internal oblique, and behind by the aponeurosis of the transversus abdominis and the aponeurosis of the posterior lamina of the internal oblique. The posterior wall is not entirely aponeurotic, for the upper fleshy fibers of the transversus abdominis muscle lie behind the rectus abdominis and almost reach the linea alba.



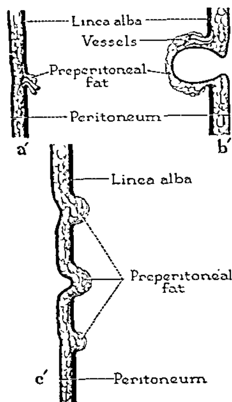


Fig. 349. EPIGASTRIC HERNIA.

Posterior view of the abdominal wall in the epigastric region with the peritoneum and preperitoneal connective tissue removed to demonstrate 3 types of epigastric hernia. Perforating blood vessels are common in this area of the linea alba, and one frequently observes a small lobule of preperitoneal fat, without a peritoneal sac, protruding through a vessel aperture as at (*a*) and shown below in sagittal section at (*a*′). The fat is incarcerated and usually painful, and the hernia requires surgical correction. At (*b*) is a large epigastric defect which contains a fully developed hernial sac as shown in sagittal section at (*b*′). An epigastric hernia such as shown at (*b*) and (*b*′) undoubtedly begins in the manner shown at (*a*) and (*a*′), with gradually more and more preperitoneal fat pushing through the small defect, enlarging it and eventually pulling the parietal peritoneum through the aperture too. Occasionally one sees a cluster of apertures through the linea alba as seen at (*c*), and the 3 defects indicated by the arrows are seen in sagittal section at (*c*′). Multiple apertures such as these are converted into a single larger defect and handled as a large epigastric hernia such as at (*b*). (From McVay: Hernia—The Pathologic Anatomy of the More Common Hernias and Their Anatomic Repair. Springfield, Charles C Thomas, 1954.)

ses freely with the superior epigastric artery. The inferior epigastric artery may be injured in a low right rectus incision, either in splitting muscle fibers or in retracting them mesially.

The *deep circumflex iliac artery* arises from the lateral aspect of the external iliac, opposite the origin of the inferior epigastric artery (Fig. 350). A short distance above the iliac crest and near the anterior superior spine, the artery gives off an ascending branch of some size which is injured when the muscle-splitting incision of McBurney is prolonged laterally.

The anterior rami of the thoracic nerves follow a curving course forward in the intercostal spaces, toward the midline of the body in front (Figs. 345, 350 to 353). Through the greater part of the course each nerve lies between the two layers of intercostal musculature, in company with a corresponding artery and vein. The upper six rami end near the sternum as anterior cutaneous branches.

The next three anterior rami in the series (seventh to ninth) pass behind the costal cartilages of the tenth to the twelfth ribs; the last three (tenth to twelfth) pass behind the ribs themselves, near their anterior ends. Leaving the thoracic region, the six rami reach the plane between the internal oblique and transverse abdominal muscles, that is, the fascial tissue between the intermediate and deep layers of lateral abdominal musculature (Figs. 350, 351). In their parietal course the nerves continue medialward, at first in the direction of the bony ribs; then, as they approach the rectus abdominis muscle, the seventh turns slightly cranialward, the eighth runs horizontally, while the remaining four run with increasing inclination caudalward. The nerves, in their thoracic and abdominal course, furnish muscular twigs; they end in cutaneous distribution after perforating the rectus muscle and sheath (Fig. 345).

The iliohypogastric nerve, which often arises in a common stem with the ilio-inguinal (from anterior rami of the twelfth thoracic as well as of the first lumbar), corresponds in behavior to

Below the midpoint between the umbilicus and the symphysis, the aponeuroses of the three flat muscles pass entirely in front of the rectus, so that the inferior extent of the rectus muscle is devoid of a posterior fibrous covering. The posterior aponeurotic layer terminates in a free crescentic margin, the *linea semicircularis* (*semilunar fold*) (of Douglas), which is fused to the underlying transversalis fascia (p. 356). The sheath contains, in addition to the rectus and pyramidalis muscles, the terminations of the lower six intercostal nerves and vessels, the last thoracic nerve, and the superior and inferior epigastric vessels (Figs. 345, 350, 351).

LINEA ALBA. The linear midline furrow, which can be seen in the anterior abdominal wall of muscular subjects, is the linea alba (Frontispiece, Part IV; Figs. 347, 348). It consists of a band of dense, crisscross fibers of the aponeuroses of the broad abdominal muscles, stretching from the xiphoid to the symphysis. Above the umbilicus it widens out, but below that level it is difficult to recognize (Fig. 366, *a*). Increased intra-abdominal pressure widens the line and favors a spreading or *diastasis* of the *recti*. In the broad, ribbon-like supraumbilical portion of the line the interlacing fibers of the aponeuroses leave small elliptical orifices through which the perforating vessels and nerves pass. Through these openings extraperitoneal areolar tissue sometimes herniates into the subcutaneous tissue, producing an *epigastric (linea alba) hernia* (*Fig. 349*). Extrusion of extraperitoneal fat may be accompanied by small sacs of the subjacent peritoneum. Whatever the volume and content of these hernias, they may give rise to subjective symptoms out of all proportion to the lesion, because of the direct pressure of the sac and contents against the nerves which sometimes emerge with them. In a person presenting an obscure upper abdominal disorder the possibility of such hernias should be investigated.

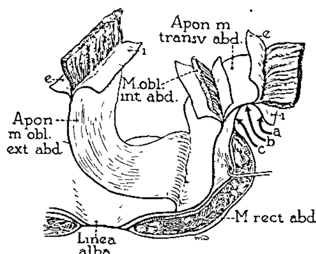


Fig. 348. STRUCTURE OF THE ABDOMINAL WALL AT A TRANSVERSE LEVEL INFERIOR TO THAT OF THE LINEA SEMICIRCULARIS; WITH SPECIAL REFERENCE TO THE DERIVATION OF THE RECTUS FASCIA.

Typically, each of the 3 layers of anterolateral abdominal musculature is covered by an external layer (at *e*) and an internal layer (at *i*). The two laminae are continued medialward where muscle fascicles give way to aponeurotic fibers. The layer which invests the deep surface of the transverse abdominal muscle is the transversalis fascia (at *a*); carried in medial direction, it next covers the aponeurosis of the transversus abdominis (at *b*); then, as a separate leaf (at *c*) it splits to enclose the rectus muscle. (*From Anson and McVay*: Anat. Record, 70: 211–25, 1938.)

VESSELS AND NERVES. The anterolateral abdominal wall receives its ARTERIAL supply from the last six intercostal and the four lumbar arteries, together with the superior and inferior epigastric and the deep circumflex iliac arteries (Fig. 350). The trunks of the *intercostal* and *lumbar arteries* run with the intercostal, iliohypogastric and ilio-inguinal nerves between the transversus abdominis and internal oblique muscles. The arterial terminations pierce the lateral margins of the rectus compartment at different levels and anastomose freely with the superior and inferior epigastric trunks.

The *superior epigastric artery*, one of the terminations of the internal mammary artery, reaches the posterior surface of the rectus muscle through the costoxiphoid interval in the diaphragm. It descends within the rectus sheath and anastomoses freely with the inferior epigastric artery. The *inferior epigastric artery* arises from the external iliac just proximal to the inguinal ligament, and at first lies in the midst of the extraperitoneal tissue at the medial side of the abdominal inguinal ring, in intimate relation with the posterior wall of the inguinal canal. The ductus deferens, as it enters the abdomen, hooks around the lateral side of the artery (Fig. 364). Accompanied by its satellite vein, the inferior epigastric artery ascends obliquely superiorly and medially toward the umbilicus, and, after piercing the transversalis fascia, enters the rectus compartment by passing in front of the linea semicircularis (semilunar fold of Douglas) (Fig. 368). It then pursues a vertical course and anastomo-

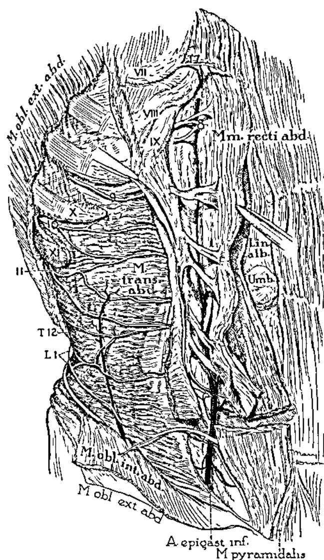


Fig. 351. ABDOMINAL PLEXUS OF THE THORACIC NERVES.

The nerves are exposed by removal of the external and internal oblique muscles and by reflection of the rectus muscle. The seventh through the twelfth thoracic nerves, and the first lumbar, are shown as they anastomose after emergence from the intercostal spaces. (From Bishop, Carr, Anson and Ashley: Quart. Bull., Northwestern Univ. M. School, 17: 209–16, 1943.)

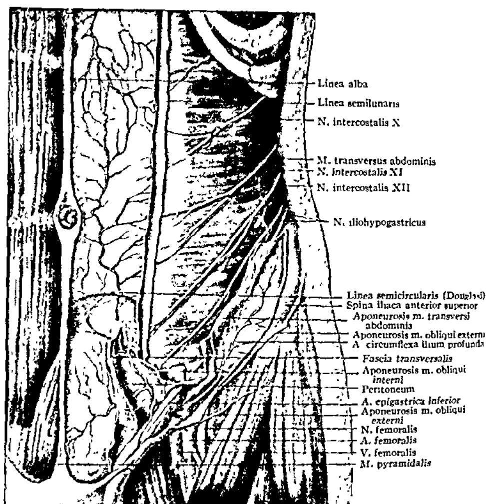


Fig. 350. MUSCLES, APONEUROSES, ARTERIES AND NERVES OF THE ANTEROLATERAL ABDOMINAL WALL. The external and internal oblique muscles have been removed from the left side.

an intercostal nerve. It runs parallel to the twelfth thoracic nerve, lateralward and downward, to pierce the transverse abdominal muscle just above the crest of the ilium. The nerve then passes between the transverse abdominal and internal oblique muscles; emerging through the substance of the latter, the nerve continues its course toward the subcutaneous inguinal ring, through the superior crus of which a cutaneous ramus passes, ultimately to reach the pubic region. During the course beneath the flat muscles of the abdomen the nerve sends muscular rami to each of them.

The ilio-inguinal nerve runs close to the iliohypogastric, but nearer the iliac crest. It gives off similar rami to the parietal muscles. Unlike the iliohypogastric nerve, however, the ilio-inguinal reaches superficial level by passing through the subcutaneous inguinal ring with the spermatic cord (or, in the female, with the round ligament of the uterus). The distal branches reach the scrotum (or labium) as anterior scrotal (or labial) rami.

While the rami lie between the internal oblique and transverse abdominal muscles, they do not remain separate; on the contrary, adjacent rami anastomose freely (Figs. 351 to 353). In a study of 137 body-halves approximately 75 per cent of the anastomoses involved the rami from the level of the tenth thoracic to that of the first lumbar. The derived nerves pierce the lateral margin of the rectus sheath, to attain the deep aspect of the rectus muscle. Passing through the muscle, the nerves attain the surface of the sheath by emerging through minute, serially arranged hiatuses in the anterior leaf of the latter (Fig. 351).

The anterior ramus of the tenth thoracic nerve reaches the skin over the rectus sheath usually at the level of the umbilicus; that of the twelfth thoracic may attain the level of the pubic symphysis. The remainder of the abdom-

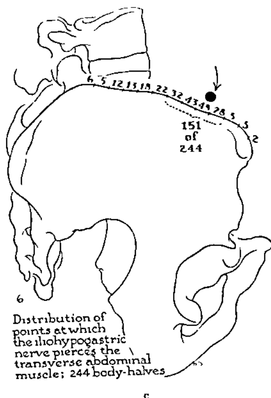
Anterior superior spine of ilium

Tubercle of pubis

4

Distribution of points at which the iliohypogastric nerve pierces the external oblique muscle. 94 body halves

a



c

A

B

5

Distribution of points at which the iliohypogastric nerve pierces the internal oblique muscle. 86 body-halves

b

Fig. 354. DISTRIBUTION OF THE POINTS OF PERFORATION OF THE ABDOMINAL WALL BY THE ILIOHYPOGASTRIC DIVISION OF THE FIRST LUMBAR NERVE.

a, Distribution points in the aponeurosis of the external oblique muscle. *b*, Points of perforation in the internal oblique muscle. *c*, Comparable distribution for the transverse abdominal muscle. It is to be noted that in approximately three-fifths of the cases the point of perforation (along the crest of the ilium) occurred in an area just posterior to the anterior superior iliac spine; this area, at the black circle, would be the preferable site for injection of an anesthetic in surgery of the inguinal region. (From Jamieson, Swigart and Anson: Quart Bull., Northwestern Univ. M. School, 26: 22–6, 1952.)

is not unusual in spinal tuberculosis, and is indicative of pressure on the main trunks of the intercostal nerves. Unless this be borne in mind, a serious mistake in diagnosis may be made, and the true nature of the case be overlooked.

Surgical Considerations

HERNIA OF THE LINEA SEMILUNARIS (SPIEGEL'S HERNIA). A posterior and anterior view of this unusual hernia and the essential steps in its repair are shown in Figure 356. The diagnosis of this defect is often difficult because the initial sac is small and hard to feel, particularly in obese patients. The neck is usually narrow, so that strangulation is a real danger.

Anatomically, these hernias are always above the point where the inferior epigastric vessels cross the linea semilunaris.

inal wall, that is, the inguinal region, is supplied by the divisions of the first lumbar nerve. These divisions, namely, the iliohypogastric and the ilio-inguinal, require special consideration, since they supply the region of inguinal hernia.

The position and course of the nerves should be borne in mind in planning abdominal incisions (Figs. 354, 355), for, although one or more may be severed without undesirable after-effect, the abdominal wall does not recover its muscle tone completely after section of the motor nerves.

The abdominal nerves supply not only the muscles, but also the overlying skin. This identity in nerve supply greatly favors reflex muscle action. Even a moderate stimulus applied to the surface of the abdomen—as, for example, palpating with a cold hand—is sufficient to throw the abdominal wall into contraction.

There are connections between the nerves of the abdominal wall and those of the viscera. When viscera are injured, or when peritonitis develops, the abdominal muscles contract through reflex action and exert a uniform pressure over the injured or inflamed parts. The muscles act more or less as splints to prevent movement as much as possible, thus keeping the injured or inflamed parts at rest. Their contraction places abdominal respiration in abeyance, fixes the lower ribs, and confines the respiratory movements chiefly to the upper region of the chest.

Pain referred to the front of the abdomen

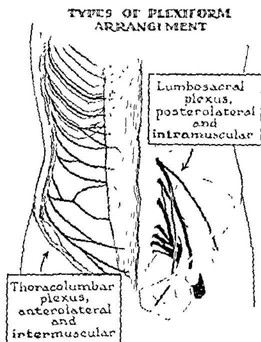


Fig. 352.

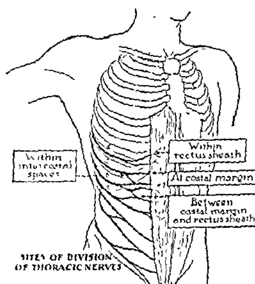


Fig. 353.

Fig. 352. PATTERNS OF PLEXIFORM ARRANGEMENT OF THE ANTERIOR RAMI OF THE THORACIC, LUMBAR AND SACRAL NERVES, SEMISCHEMATIC.

The large lumbar and sacral plexuses are shown on the specimen's left; psoas major and iliacus muscles have been removed in order to demonstrate the manner in which the rami contribute to the plexuses immediately distal to the point at which they emerge from the intervertebral foramina. The less bulky, and hence less conspicuous, plexus formed by the thoracic nerves is pictured on the specimen's right half. Here the anastomoses occur as the rami course between the internal oblique and transverse abdominal muscles, the intercommunications occurring just beyond the points at which the nerves leave the intercostal spaces. (From Bishop, Carr, Anson and Ashley: Quart. Bull., Northwestern Univ. M. School, 17: 209–16, 1943.)

Fig. 353. TOPOGRAPHICAL SITES OF DIVISION AND COMMUNICATION OF THE ANTERIOR RAMI OF THE THORACIC NERVES ON, OR ADJACENT TO, THE ANTEROLATERAL ABDOMINAL WALL.

Division of a ramus may take place at any one of 4 points: within the rectus sheath; at the costal margin; within an intercostal space; or on the anterior abdominal wall (usually as the nerves course forward between the internal oblique and the transverse abdominal muscles). As soon as the nerves emerge from the intercostal spaces, they establish intercommunications, just as the lumbar and sacral do upon leaving the intervertebral foramina. (From Bishop, Carr, Anson and Ashley: Quart. Bull., Northwestern Univ. M. School, 17: 209–16, 1943.)

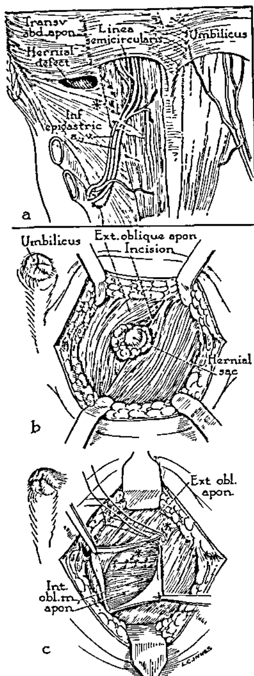


Fig. 356. HERNIA OF LINEA SEMILUNARIS (SPIEGEL'S HERNIA).

a, Posterior view of the aponeurotic defect in a case of left semilunar or so-called Spiegel's hernia. The bracket labeled with the asterisk indicates the most common distribution of hernias in the linea semilunaris. If below the inferior epigastric vessels, it is through Hesselbach's triangle and is therefore a direct inguinal hernia. *b*, Anterior view of the left semilunar hernia presenting through the external oblique aponeurosis. The exposure is through a transverse skin incision. *c*, The peritoneal sac has been removed and the aponeurotic defect closed (asterisk). Aponeurotic fibers of the transversus abdominis and internal oblique muscle have been sutured. External oblique aponeurosis in process of closure. The normal musculo-aponeurotic mechanism is firm, so that there should be no recurrences. (From McVay: Hernia—The Pathologic Anatomy of the More Common Hernias and Their Anatomic Repair. Springfield, Charles C Thomas, 1954.)

medial to the incision. A *pararectus incision* is therefore undesirable.

The main blood supply to the anterior abdominal wall comes from the superior and inferior epigastric arteries, the latter being most generous. A further contribution is derived from the deep circumflex iliac and lumbar and intercostal arteries. Little anastomosis occurs across the midline, but elsewhere it is so plentiful that division by transverse incisions carries no danger.

VERTICAL OR TRANSVERSE ABDOMINAL INCISIONS. Vertical incisions were first used and have widespread popularity. They can be made rapidly because no major blood vessels are divided, this being particularly true for the midline or paramedian approach. They can easily be extended from the upper abdomen to the pubes in the event of incorrect diagnosis. This thought is a boon to the lesser surgeon who gives little attention to the diagnosis preoperatively and believes in "open them up and look." Vertical approach gives ready access to the epigastrium, particularly when the subcostal angle is narrow. For large exposures, a lateral transverse extension is sometimes added (Fig. 357).

Transverse incisions are not new, but have become more popular since anatomic studies showed that division of the anterior abdominal wall muscles, particularly the recti, does not interfere with nerve supply and produce paralysis. Also, it was thought that the divided recti would retract considerably and leave a weak wall. This does not occur; the final healing brings the muscle ends almost together, forming a new transverse band. Originally, to save the recti, efforts were made to retract this muscle, but now transverse incision of all layers is commonly done. While the opening of a transverse incision is slower than for a vertical, the closure is easier because the layers come together with less tension. The transverse skin incision can largely be made to follow Langer's lines and thus shows less tendency to widen. Transverse incisions cause less splinting of the abdomen postoperatively and therefore less interference with respiration.

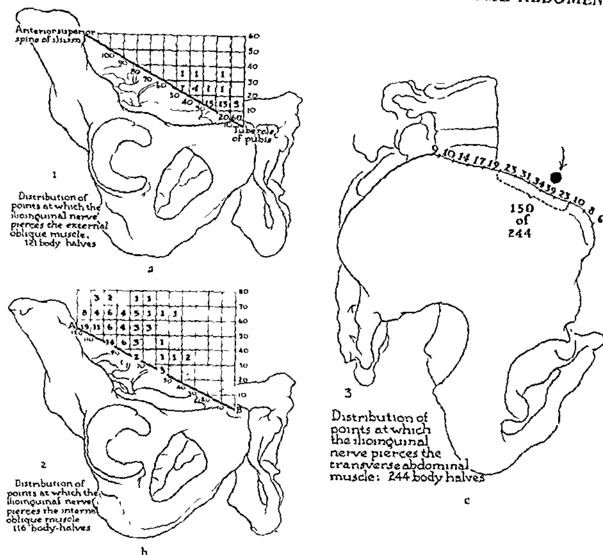


Fig. 355. DISTRIBUTION OF THE POINTS OF PARIETAL PERFORATION BY THE ILIO-INGUINAL DIVISION OF THE FIRST LUMBAR NERVE.

Here, as in the preceding figure, the observations for the outer (*a*) and middle (*b*) of the three anterolateral abdominal layers are charted in triangular and rectangular plaques, the transverse and vertical boundaries of which measure approximately 10 mm.; data for the innermost layer (*c*) are recorded along the crest of the ilium, to which both nerves remain in close proximity as they pierce the transverse abdominal layer to reach the fibrous layer between the latter muscle and the internal oblique. *a*, Distribution points of perforation by the ilio-inguinal nerve in the aponeurosis of the external oblique muscle. *b*, Points at which the nerve pierces the internal oblique muscle, shown along the line of the inguinal ligament or in plaques measuring 10 mm. in width and height. *c*, Comparable records for the transverse abdominal muscle. Significance of the marker and arrow is explained in the legend for the preceding figure. (From Jamieson, Swigart and Anson: Quart. Bull., Northwestern Univ. M. School, 26: 22–6, 1952.)

Abdominal Incisions in General. These are made through those parts of the abdominal wall which give the freest access with the least disturbance of nerve supply to the muscles. The anteriorly situated recti and the lateral flat or oblique muscles (external oblique, internal oblique and transversus abdominis) receive their nerve supply from the lower six intercostal and first lumbar nerves. It is important to know that a rich anastomosis of these nerves occurs in the *intercostal spaces* and in the abdominal wall between the layer of the internal oblique and transversus abdominis, so that in these areas it is possible to cut two, and sometimes even three, of the nerves without noticeable loss of function. A different situation occurs farther forward; from the lateral border of the recti onward, little if any anastomosis occurs. A transverse incision through the rectus muscle results in the least possible damage to its nerve supply. Conversely, a vertical incision through the rectus muscle, particularly through the *lateral portion* (pararectus incision), denervates that portion of the muscle

left upper quadrant transverse incision (Fig. 358, *A*).

When these incisions involve the oblique muscles for only short distances, division is usually made in the line of the muscle fibers; when longer extensions are needed, these lateral muscles are cut in the line of the skin incision, and heal with no resultant weakness.

RIGHT (OR LEFT) SUBCOSTAL INCISION (Fig. 357, *A*). This offers an excellent exposure of the biliary system, duodenum and the head of the pancreas. On the left it can be well used for a splenectomy. By a little retraction of the lower skin flap the anterior rectus sheath and muscle are divided transversely. The external oblique aponeurosis and muscle are split upward in the line of its fibers. The lower muscle flap is retracted downward, and the internal oblique and transversus are split into the flank in the direction of the skin incision. This usually divides the ninth intercostal, but the tenth can be stretched a bit and retracted out of the way.

In making this incision, Singleton* advised dividing the anterior rectus sheath and external oblique in the direction of the skin incision, which is almost at a right angle to the direction of the fibers of the latter. Continuing in the same line, the incision cuts the internal oblique the other way, but the transverse abdominal muscle is divided in the direction of its fibers (Fig. 345). Singleton freed the rectus and retracted it medially. The posterior rectus sheath and peritoneum were opened in the line of the skin incision.

* Singleton and Blocker: J.A.M.A., 112: 122–7, 1939; Singleton: Surg., Gynec. & Obst., 70: 1051–3, 1940.

TRANSVERSE MIDABDOMINAL INCISION (Fig. 358, *D*, *F*). This incision of great utility is made a few centimeters above or below the umbilicus and on the right or left side as indicated. It offers excellent exposure of the biliary system, duodenum, head of the pancreas, small intestines, or the various areas of the colon: ileocecal, right colon, transverse colon, splenic flexure, descending colon or upper sigmoid regions. The authors prefer it to the subcostal incision. The rectus muscle is transected, and the lateral muscles are usually divided in line with the skin incision. A few surgeons incise the latter in the direction of their fibers.

This incision made below the umbilicus also offers an excellent retroperitoneal approach to the lumbar sympathetics, ureters and inferior vena cava.

TRANSVERSE UMBILICAL INCISION. This inci-

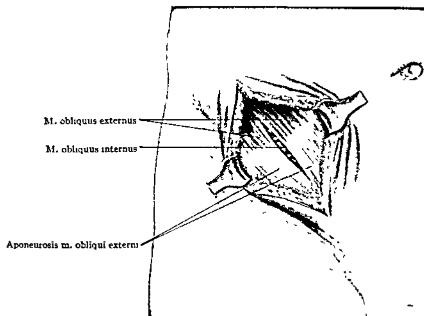


Fig. 359. MC BURNEY MUSCLE-SPLITTING APPROACH TO THE CECUM AND APPENDIX.

The skin incision begins about 4 cm. medial to the right anterior superior spine a little above an imaginary line running from this spine to the umbilicus, and extends downward roughly parallel to the inguinal ligament for 5 to 8 cm. (see Fig. 357, *M*). The subcutaneous fat and Scarpa's fascia are divided in the direction of the skin incision down to the external oblique muscle. The aponeurosis of this muscle is divided in the direction of its fibers.

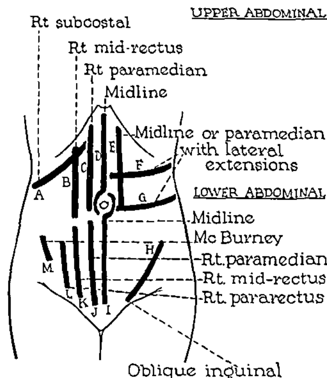


Fig. 357. PRINCIPAL VERTICAL ABDOMINAL INCISIONS.

These may be made on either side, depending upon the site of the surgical lesion.

The incidence of wound disruption and hernia is also less for transverse incisions than for vertical. In recent years more surgeons like the general usefulness and good features of transverse abdominal incisions (Fig. 357).

Specific incisions will now be presented briefly. In selecting one or the other, the basic need is for adequate exposure to perform the proper surgical procedure. It has been well said that good exposure is the cheapest step in any operation. One must remember that wounds heal from side to side, and a longer incision will not delay the patient's convalescence.

MEDIAN UPPER ABDOMINAL INCISIONS. Excellent and widely used approaches to the stomach, duodenum and pancreas are offered by *vertical midline* or *right* or *left paramedian incisions* (Fig. 357, *D*, *C*, *E*). The latter may split the rectus muscle or retract it laterally. For better exposure of the body and tail of the pancreas or the spleen, a lateral transverse extension of the left paramedian incision may be done (Fig. 357, *F*, *G*).

TRANSVERSE UPPER ABDOMINAL INCISIONS. This approach, crosscutting all layers (Fig. 358, *B*), gives excellent access to the stomach, duodenum and pancreas. It is situated about halfway between the xiphoid process and the umbilicus. For lesions of the tail of the pancreas or gastric cardia, a left lateral extension into the oblique muscles can be made. On rare occasions an incision up the linea alba is added for better management of a high subtotal or total gastrectomy. Also for the latter and for splenectomy, good access is afforded by a high

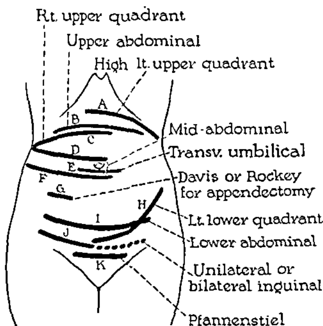


Fig. 358. PRINCIPAL TRANSVERSE ABDOMINAL INCISIONS.

These are preferred by an increasing number of surgeons in recent years, and are usable on either side, depending upon the site of the surgical lesions. (From Rees and Coller: Arch. Surg., 47: 136–46, 1943; Coller and Maclean: Operative Technique, General Surgery, W. H. Cole. New York, Appleton-Century-Croft, Inc.)

left upper quadrant transverse incision (Fig. 358, *A*).

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In making this incision, Singleton* advised dividing the anterior rectus sheath and external oblique in the direction of the skin incision, which is almost at a right angle to the direction of the fibers of the latter. Continuing in the same line, the incision cuts the internal oblique the other way, but the transverse abdominal muscle is divided in the direction of its fibers (Fig. 345). Singleton freed the rectus and retracted it medially. The posterior rectus sheath and peritoneum were opened in the line of the skin incision.

* Singleton and Blocker: J.A.M.A., 112: 122–7, 1939; Singleton: Surg., Gynec. & Obst., 70: 1051–3, 1940.

TRANSVERSE MIDABDOMINAL INCISION (Fig. 358, *D, F*). *This incision of great utility is* made a few centimeters above or below the umbilicus and on the right or left side as indicated. It offers excellent exposure of the biliary system, duodenum, head of the pancreas, small intestines, or the various areas of the colon: ileocecal, right colon, transverse colon, splenic flexure, descending colon or upper sigmoid regions. The authors prefer it to the subcostal incision. The rectus muscle is transected, and the lateral muscles are usually divided in line with the skin incision. A few surgeons incise the latter in the direction of their fibers.

This incision made below the umbilicus also offers an excellent retroperitoneal approach to the lumbar sympathetics, ureters and inferior vena cava.

TRANSVERSE UMBILICAL INCISION. This inci-

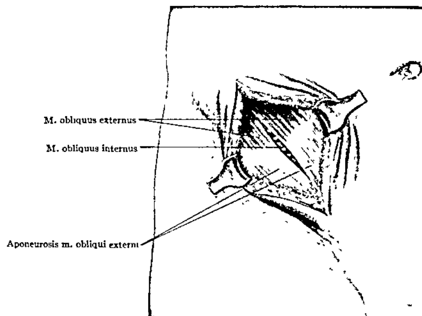


Fig. 359. MC BURNEY MUSCLE-SPLITTING APPROACH TO THE CECUM AND APPENDIX.

The skin incision begins about 4 cm. medial to the right anterior superior spine a little above an imaginary line running from this spine to the umbilicus, and extends downward roughly parallel to the inguinal ligament for 5 to 8 cm. (see Fig. 357, *M*). The subcutaneous fat and Scarpa's fascia are divided in the direction of the skin incision down to the external oblique muscle. The aponeurosis of this muscle is divided in the direction of its fibers.

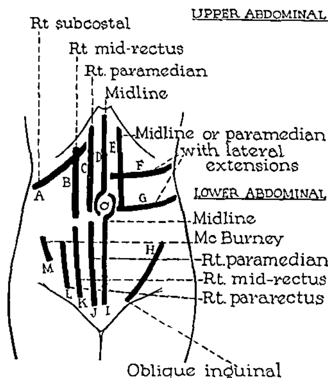


Fig. 357. PRINCIPAL VERTICAL ABDOMINAL INCISIONS.

These may be made on either side, depending upon the site of the surgical lesion.

The incidence of wound disruption and hernia is also less for transverse incisions than for vertical. In recent years more surgeons like the general usefulness and good features of transverse abdominal incisions (Fig. 357).

Specific incisions will now be presented briefly. In selecting one or the other, the basic need is for adequate exposure to perform the proper surgical procedure. It has been well said that good exposure is the cheapest step in any operation. One must remember that wounds heal from side to side, and a longer incision will not delay the patient's convalescence.

MEDIAN UPPER ABDOMINAL INCISIONS. Excellent and widely used approaches to the stomach, duodenum and pancreas are offered by *vertical midline* or *right* or *left paramedian incisions* (Fig. 357, *D*, *C*, *E*). The latter may split the rectus muscle or retract it laterally. For better exposure of the body and tail of the pancreas or the spleen, a lateral transverse extension of the left paramedian incision may be done (Fig. 357, *F*, *G*).

TRANSVERSE UPPER ABDOMINAL INCISIONS. This approach, crosscutting all layers (Fig. 358, *B*), gives excellent access to the stomach, duodenum and pancreas. It is situated about halfway between the xiphoid process and the umbilicus. For lesions of the tail of the pancreas or gastric cardia, a left lateral extension into the oblique muscles can be made. On rare occasions an incision up the linea alba is added for better management of a high subtotal or total gastrectomy. Also for the latter and for splenectomy, good access is afforded by a high

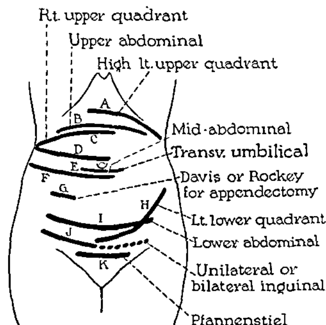


Fig. 358. PRINCIPAL TRANSVERSE ABDOMINAL INCISIONS.

These are preferred by an increasing number of surgeons in recent years, and are usable on either side, depending upon the site of the surgical lesions. (From Rees and Coller: Arch. Surg., 47: 136–46, 1943; Coller and Maclean: Operative Technique, General Surgery, W. H. Cole. New York, Appleton-Century-Croft, Inc.)

sion, made 4 to 7 cm. long, lies in the direction of Langer's lines about the level of the anterior superior iliac spine. It straddles the semilunar line so that one third is medial and two thirds are lateral. The subcutaneous fat and Scarpa's fascia are cut in the direction of the skin incision down to the lateral muscles. Then, as for a McBurney incision, the external oblique aponeurosis is incised in the direction of its fibers and widely retracted. At the semilunar line the aponeurotic junction of the internal oblique and transversus abdominis muscles is picked up and incised transversely for sufficient distance to insert two fingers and thus bluntly separate the muscle fibers laterally. This lessens bleeding from the muscles. The transversalis fascia and peritoneum are then divided transversely. Extension of this incision upward can be made by incising along the lateral border of the rectus sheath; extension medially is easily carried out by cross-cutting the rectus fasciae and muscle.

Besides being well able to remove the appendix through the Davis or Davis-Rockey incision, the surgeon can feel the body of the uterus and see the right tube and ovary. The terminal ileum can be delivered if necessary to search for a Meckel diverticulum (Fig. 494, p. 505).

In both the McBurney and the Davis incisions, care must be taken not to cut the iliohypogastric nerve lying under the internal oblique muscle (Fig. 360).

Lower Abdominal Vertical Incisions (Fig. 357, *I* to *K*). These approaches are commonly used for access to pelvic structures, the sigmoid colon and right colon. The right or left paramedian, made 2 cm. from the midline, is preferable to the midline incision and may be easily extended to any required length. The rectus muscle is freed posteriorly and retracted, followed by a vertical incision through the posterior rectus sheath, transversalis fascia and peritoneum. There is no posterior rectus sheath below the semicircular line of Douglas (Fig. 350).

A *pararectal incision* (Fig. 357, *L*) is a poor choice of several possibilities in the area, having the great disadvantage that, if reasonably long, it cuts too much of the nerve supply to the rectus muscle, and definite weakness often becomes evident. A short pararectus approach, the *Kammerer* or *Battle* incision, is used by some surgeons for an appendectomy. A 6- to 8-cm. skin incision centered just above the right anterior superior spine is made 1 cm. medial to the lateral edge of the rectus muscle. In the same line the anterior rectus sheath is divided and the muscle freed and retracted medially. Again in the same direction the posterior rectus sheath and peritoneum are incised. Any vertical extension of this incision cuts too many nerves (Fig. 351).

A lower abdominal vertical *midrectus incision* (Fig. 357, *K*) is of wide use, but, if long, denervates the rectus muscle medial to the incision. By using a paramedian incision it is likely that the same operation can be done and this denervation avoided.

Left Lower Quadrant Oblique Incision. Coller and Maclean described this incision for the abdominal portion of the combined abdominoperineal operation or for low sigmoid resections. The skin incision begins about the midline 2.5 cm. above the symphysis and extends in a flat curve (Fig. 358, *H*) to a point 5 cm. above and medial to the left anterior superior spine. Subcutaneous tissue is dissected from the anterior fascia for 2 to 3 cm. and, with the skin, is retracted up and down. The left rectus fascia and muscle are divided transversely, the incision then extending laterally and upward through the external oblique muscle in the direction of its aponeurosis and fibers for the full length of the skin incision. From the semilunar line the internal oblique and transversus abdominis are divided in the direction of their fibers to the iliac wing, care being taken to expose and retract the iliohypogastric nerve lying laterally between the external and internal oblique muscles. The transversalis fascia and peritoneum are divided in the line of the aponeurotic incision. For wider exposure the right rectus muscle can be developed and divided.

Lower Abdominal Median Transverse Incisions. A few gynecologists are using a wide lower abdominal transverse incision of all layers (Fig. 358, *I*). This follows transverse lines or creases at a level one-third of the way upward from the symphysis pubis to the umbilicus. Both recti are transected, and lateral extensions can be made by splitting the oblique muscles in the direction of their fibers.

The *Pfannenstiel incision*, placed within the pubic hair line (Fig. 358, *K*), offers an approach for some of the smaller gynecologic operations. Its chief objection is lack of wide exposure. The incision follows the skin lines just above the pubis. The anterior rectus sheath and linea

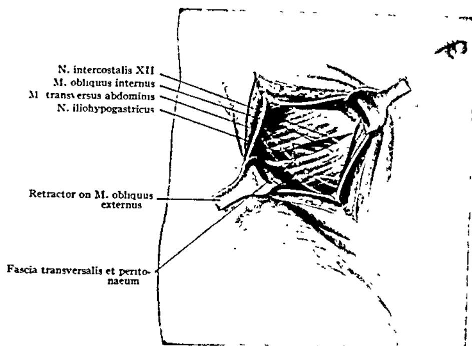


Fig. 360. MC BURNEY INCISION (CONTINUED).

The aponeurosis of the external oblique muscle is retracted and the internal oblique divided in the direction of its muscle fibers. The transversus abdominis muscle is similarly split after lateral retraction of the iliohypogastric nerve.

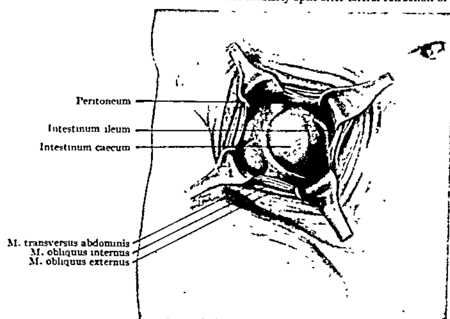


Fig. 361. MC BURNEY INCISION (CONCLUDED).

With wide retraction of the muscle, the transversalis fascia and peritoneum are encountered and incised transversely. The cecum is found and the appendix base located at the ends of the converging longitudinal bands. Wound closure restores the natural crossing of the three lateral muscles.

sion, made just below the umbilicus or converted to an elliptical incision by an extension surrounding the umbilicus above, offers an excellent approach to the umbilical region for repair of hernias or other umbilical lesions (Fig. 358, *E*).

INCISIONS FOR APPENDECTOMY. The oblique muscle-splitting *incision of McBurney* (Figs. 357, *M*; 359 to 361) is a time-honored approach devised to minimize postoperative weakness by dividing the three lateral abdominal muscles in the direction of their fleshy and tendinous fibers. It is commonly used, but, like all incisions across skin lines, it tends to widen with time.

The transverse *Davis or Rockey* incision (Fig. 358, *G*) is a fine approach to the appendix and is preferred by the authors. The skin inci-

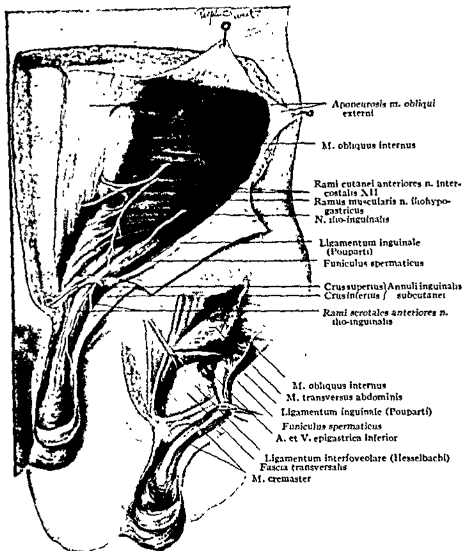


Fig. 363. SUPERFICIAL AND DEEP STRUCTURES OF THE INGUINO-ABDOMINAL REGION.

The inset shows the internal oblique muscle sectioned to indicate the underlying transversus abdominis; the cord is retracted inferiorly to show the floor of the inguinal canal; part of the transversalis fascia is removed to show the inferior epigastric vessels.

SURFACE ANATOMY. The landmarks of clinical and operative significance are the readily palpable *anterior superior iliac spine* and the less easily palpable *pubic tubercle*. In obese persons the *pubic crest* is difficult to make out, but it may be determined accurately enough in the male by measuring two fingerbreadths above the suspensory ligament of the penis. The *inguinal ligament*, especially under anesthesia, can be palpated readily. A swelling definitely located above the ligament is suggestive of inguino-abdominal origin, while one below is suggestive of origin in the thigh. The size and laxity of the *subcutaneous inguinal (external abdominal) ring* may be determined by invaginating the scrotum with the tip of the index finger and carrying the finger over the tubercle against the opening. The ring, when normal in size, cannot be entered; but, when dilated, admits the finger readily. An impulse against the finger, produced by coughing, affords some appreciation of the resistance of the back wall of the canal and the presence of actual or potential hernia.

INGUINAL MUSCULATURE. The acknowledged weakness of the abdominal wall in the region of the inguinal trigone is accounted for in several ways: first, the substitution of an aponeurosis of no great strength for the thick muscular layer of the external oblique; second, the descent of the testis and the vaginal process of peritoneum in the male, and of the

alba are divided transversely, then reflected upward off the recti for 8 to 10 cm. The rectus muscles are then retracted laterally, and the transversalis fascia and peritoneum are divided in the midline.

TRANSVERSE INGUINAL INCISION (Fig. 358, *J*). This incision, lying along the transverse skin lines or creases, gives excellent approach for the average herniorrhaphy operation and leaves an inconspicuous scar. Made approximately 10 to 12 cm. long, it is centered about the middle of the inguinal canal. By symmetrical extension to the opposite side a bilateral herniorrhaphy is easily done. Skin and subcutaneous flaps need to be raised a bit more than for the oblique incision, but the further steps in the hernia repair can easily be accomplished.

OBLIQUE INGUINAL INCISION (Fig. 357, *H*). This is the most common incision for repair of inguinal hernia, and usually for femoral hernia. It begins 2 cm. above and lateral to the pubic spine, then extends upward and slightly inward, not quite parallel to the inguinal ligament, for about two thirds of the distance to the anterior superior spine. Subsequent steps will be discussed under inguinal hernia (p. 390).

ABDOMINAL PARACENTESIS. Abdominal paracentesis, or puncture of the peritoneal cavity, is done for diagnostic purposes or for the evacuation of peritoneal fluid. The site for the paracentesis generally is the linea alba midway between the umbilicus and the symphysis. Before the trocar is introduced, the skin should be incised. After it has entered the peritoneal cavity the patient should sit upright, since in that position fluid gravitates into the lower abdomen and pelvis. Paracentesis may also be done in the semilunar line or midway between the anterior superior spine and the umbilicus.

INGUINO-ABDOMINAL REGION (INGUINAL TRIGONE)

DEFINITION AND BOUNDARIES. The inguino-abdominal region is the subsidiary area of the anterolateral abdominal wall which is limited by the inguinal ligament, the lateral margin of the rectus muscle, and a horizontal line from the anterior superior iliac spine to the lateral rectus margin (Fig. 362). Its surgical importance is derived from the high incidence of inguinal hernias. In the consideration of this area are reviewed the anatomic conditions which permit development of hernias, their classification, and the operative measures designed for their radical cure.

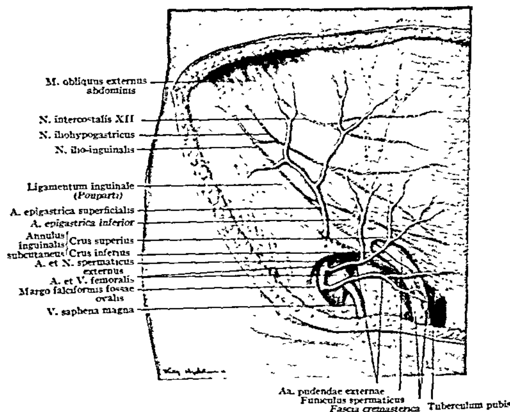


Fig. 362. SUPERFICIAL VIEW OF THE INGUINO-ABDOMINAL REGION AND THE [illegible]

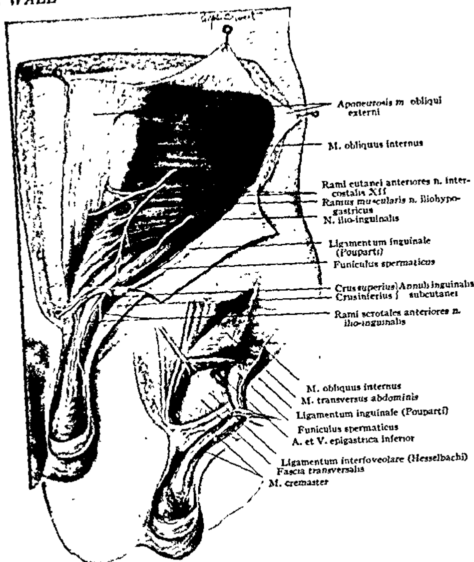


Fig. 363. SUPERFICIAL AND DEEP STRUCTURES OF THE INGUINO-ABDOMINAL REGION.
The inset shows the internal oblique muscle sectioned to indicate the underlying transversus abdominis; the cord is retracted inferiorly to show the floor of the inguinal canal; part of the transversalis fascia is removed to show the inferior epigastric vessels.

Surface Anatomy. The landmarks of clinical and operative significance are the readily palpable *anterior superior iliac spine* and the less easily palpable *pubic tubercle*. In obese persons the *pubic crest* is difficult to make out, but it may be determined accurately enough in the male by measuring two fingerbreadths above the suspensory ligament of the penis. The *inguinal ligament*, especially under anesthesia, can be palpated readily. A swelling definitely located above the ligament is suggestive of inguino-abdominal origin, while one below is suggestive of origin in the thigh. The size and laxity of the *subcutaneous inguinal* (*external abdominal*) *ring* may be determined by invaginating the scrotum with the tip of the index finger and carrying the finger over the tubercle against the opening. The ring, when normal in size, cannot be entered; but, when dilated, admits the finger readily. An impulse against the finger, produced by coughing, affords some appreciation of the resistance of the back wall of the canal and the presence of actual or potential hernia.

Inguinal Musculature. The acknowledged weakness of the abdominal wall in the region of the inguinal trigone is accounted for in several ways: first, the substitution of an aponeurosis of no great strength for the thick muscular layer of the external oblique; second, the descent of the testis and the vaginal process of peritoneum in the male, and of the

round ligament and its vaginal process of peritoneum (canal of Nuck) in the female; and, third, the fact that the inferior border of the internal oblique and transversus abdominis (conjoined muscle and tendon) falls short of the inguinal ligament over its medial two thirds. This disposition leaves a weak area between the inguinal ligament, the lower margin of these muscles, and the lateral border of the rectus; this weak area must bear the brunt of intra-abdominal pressure. The inguinal canal, by traversing the entire thickness of the abdominal wall, not only weakens it, but also provides an interstitial track along which hernial protrusions may travel (Figs. 362, 363). There is little doubt that the erect posture of man is a predisposing cause of inguinal hernia.

The EXTERNAL OBLIQUE MUSCLE becomes tendinous over the confines of this region (Fig. 362). Its lower fibers condense into the inguinal ligament and pubis, and a small mesial portion is reflected as the *lacunar ligament* (Fig. 364). Immediately above the crest of the pubis the aponeurosis presents a deficiency or gap, the *subcutaneous inguinal ring*, through which issues the spermatic cord in the male and the round ligament in the female. Arching *intercolumnar* (*intercrural*) *fibers* bind the borders of the ring together and form the outermost layer of the sheath of the cord. The fibers are designed to prevent enlargement of the ring by further spreading of the external oblique aponeurosis (Fig. 370, *b*). The margins of the ring can be made out distinctly only when the thin layer of fascia embracing the intercolumnar fibers, the *intercolumnar* (*intercrural*) *fascia*, is removed. The ring is triangular, and its long axis is directed obliquely, inferiorly and mesially. The margins sometimes are called the medial and lateral *crura* (pillars) of the ring, but are described much more accurately as the superior and inferior crura. The inferior or lateral crus is formed mainly by the cordlike medial extremity of the inguinal ligament which is attached to the pubic spine. The superior or medial crus is thinner and flatter and attaches to the front of the symphysis. The shape and size of the ring vary widely in different persons (Fig. 346, *a*).

The anterior and inferior bulging of the external oblique muscle, before reflection posteriorly and superiorly as the inguinal ligament, forms a bed, the *inguinal groove*, for the spermatic cord, and a sharp free margin for the inguinal ligament.

Only the inferior fibers of the INTERNAL OBLIQUE and TRANSVERSUS ABDOMINIS MUSCLES, those fibers which have a common origin over the lateral third or half of the inguinal ligament, properly belong in the inguinal region (Figs. 363, 364). Their superimposed muscle bundles become tendinous and fuse with one another at about the lateral margin of the rectus muscle. The resulting broad, frontally disposed *inguinal falx* or *conjoined tendon* inserts partly into the anterior sheath of the rectus muscle, but mainly into the crest of the pubis. When well developed, it forms a resistant arch behind the medial portion of the inguinal canal. The lateral margin of the inguinal falx sometimes can be palpated. The fibers of both muscles and their tendon arch inferiorly and medially, and cross the cord obliquely. They are first anterior to the cord, next superior to it, and then posterior to it.

From the muscular inferior border of the internal oblique, at the point where the testis emerged to descend into the scrotum, the *cremaster muscle* is given off. In its descent the testis impinges against the lowermost fibers of the internal oblique muscle, which form cremasteric loops over the cord, that maintain their lateral attachment at the inguinal ligament and their medial attachment at the pubis. Lateral, mesial and anterior bundles of cremasteric fibers can be differentiated as contributing to the formation of the spermatic sheath.

TRANSVERSALIS FASCIA. In the unprotected interval below the inferior margin of the internal oblique and transversus abdominis muscles, the transversalis fascia shows unusual development and reinforcement. It is inserted firmly into the iliac fascia above the line of fusion of the iliac fascia and inguinal ligament, is intimately fixed about the femoral vessels, and spreads out over the femoral ring like a diaphragm (*crural septum*). A vertical reinforcement for the fascia is afforded by the lateral expansion of the rectus tendon (*ligament of Henle*), which extends laterally to insert into the pubic crest and spine posterior to the insertion of the inguinal falx (conjoined tendon). The *interfoveolar ligament*, another strong, more or less vertical reinforcement, extends from the lowermost margin of the transversus abdominis muscle to the superior ramus of the pubis (Fig. 364). This ligament, hemmed by the inferior epigastric artery, holds the spermatic cord in the lateral a

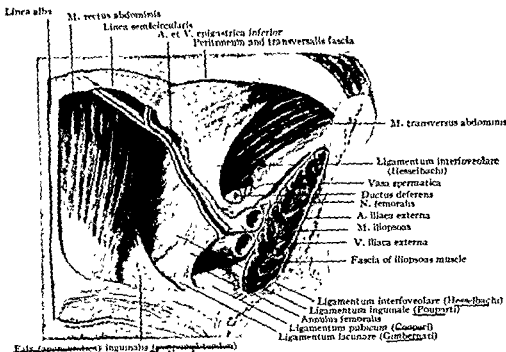


Fig. 364. POSTERIOR VIEW OF THE INGUINO-ABDOMINAL AND INGUINOFEMORAL REGIONS AFTER THE PERITONEUM AND TRANSVERSALIS FASCIA HAVE BEEN REMOVED.

inguinal region, and separates the abdominal inguinal ring from the *triangle of Hesselbach.* The base of the triangle is formed by the mesial portion of the inguinal ligament, the mesial side by the lateral border of the rectus abdominis muscle, and the lateral side by the inferior epigastric artery. Occasionally, hernia occurs through the transversalis fascia in the floor of Hesselbach's triangle (p. 385). The testicle, in its descent, evaginates the transversalis fascia, from which is derived the most intimate covering of the spermatic sheath, the *internal spermatic (infundibuliform) fascia.*

PERITONEUM, EXTRAPERITONEAL AREOLAR TISSUE AND PERITONEAL FOSSAE. Before the parietal PERITONEUM covering the posterior surface of the inguino-abdominal region reaches the inguinal ligament, it is reflected posteriorly and superiorly to clothe the iliac fossa. The reflection of the peritoneal cul-de-sac occurs at a higher level than the line of adhesion of the transversalis fascia to the iliac fascia. In consequence, there is a space between the upward reflection of the serosa and the inguinal ligament which is filled with abundant EXTRAPERITONEAL AREOLAR TISSUE. The possibility of a part of the bladder occupying the space always must be considered in operating upon direct inguinal hernias (p. 390). An incision parallel to and 1 cm. above the ligament, with upward retraction of the contents of the inguinal canal, exposes the transversalis fascia over the inferior epigastric vessels. Here the inferior epigastric and external iliac arteries may be ligated extraperitoneally. The peritoneum is applied loosely to the transversalis fascia except about the abdominal inguinal ring.

When the anterior abdominal wall is viewed from behind, certain peritoneal ridges, or cordlike structures, are seen converging from the pelvis and iliac fossa toward the umbilicus (Fig. 386). These are the urachus in the midline, and the obliterated umbilical and inferior epigastric arteries on each side. These folds delimit intervals or PERITONEAL FOSSAE of surgical interest, since they present important relations to various forms of hernias (Fig. 368).

The *external fossa* lies lateral to the inferior epigastric artery; when its peritoneal covering is removed, the internal abdominal ring is brought into view, with the vas deferens and spermatic vessels converging toward it. When a hernia leaves the abdomen through the external inguinal fossa, it enters the inguinal canal at its inlet and traverses its entire length before emerging through the subcutaneous inguinal ring. For this reason, and because it lies outside the inferior epigastric artery, it is called an external or indirect inguinal hernia.

The *middle inguinal fossa* lies between the inferior epigastric artery laterally and the obliterated umbilical artery mesially. At this level the abdominal wall is weak, since the inferior margins of the internal oblique and transversus abdominis muscles fail to reach the inguinal ligament. The result is that, over the lower part of the fossa, the transversalis fascia alone separates the sac of the hernia from the outlet of the canal at the external ring. A hernia originating within this fossa makes its way through the abdominal wall by pushing the transversalis fascia ahead of it and emerging through the subcutaneous inguinal ring. It escapes to the lateral side of the conjoined tendon, which normally overlies the main part of the fossa, but in this variety of hernia is related closely to the neck of the sac on its superior and medial aspect. This hernia, therefore, does not traverse the entire inguinal canal, but enters the canal near its outlet, close behind the subcutaneous (external) abdominal ring. It lies mesial to the inferior epigastric artery, and is designated an internal or direct inguinal hernia. In direct hernia the falx inguinalis occasionally may be pushed forward by the herniating mass.

The *internal inguinal fossa*, or *supravesical space*, is bounded laterally by the obliterated umbilical artery and mesially by the urachus. At this level the abdominal wall offers considerable resistance to intra-abdominal pressure because of the presence of the rectus muscle and the inguinal falx (conjoined tendon). A hernia rarely originates here because of the presence of these structures.

VESSELS AND NERVES. The *inferior epigastric artery* arises from the anteromedial surface of the external iliac artery about 1 cm. superior to the inguinal ligament. It runs mesially for a short distance, parallel to the inguinal ligament, and then obliquely upward and mesially in the extraperitoneal fat along the medial margin of the internal ring toward the linea semicircularis (Figs. 345, 350).

The principal nerves are the iliohypogastric and ilio-inguinal, both of which are branches of the first lumbar nerve. The *iliohypogastric nerve* runs forward in the abdominal wall near the superior margin of the iliac crest, and there divides into hypogastric and iliac branches (Figs. 345, 348).

The *ilio-inguinal nerve* enters the region at a somewhat lower level than the iliohypogastric and, after crossing part of the iliac fossa, enters the inguinal canal. It runs anteriorly beneath the aponeurosis of the internal oblique immediately above the inguinal ligament, and emerges from the subcutaneous inguinal ring (Figs. 345, 363).

DESCENT OF THE TESTICLE AND ITS RELATION TO THE VAGINAL PROCESS OF PERITONEUM. The testicle develops between the transversalis fascia and peritoneum. The gland is differentiated early in the lumbar region. As growth and development proceed, the testicle occupies relatively lower levels, and toward the end of the third intrauterine month has reached the vicinity of the anterior abdominal wall and lies in the iliac fossa close to the pelvic brim (Fig. 365). Passing upward from the gland is a fold of peritoneum, the *plica vascularis*, in which the spermatic vessels lie. Passing downward from the testicle to the anterior abdominal wall is another fold, in which lies the *gubernaculum testis*.

A series of changes takes place preparatory to further movement of the testicle. An outpocketing of peritoneum, the *processus vaginalis peritonaei*, appears at the site of the future abdominal inguinal ring, and emerges through the anterior abdominal wall. At this time there is a rudiment of scrotum on each side of the rudimentary penis, made up of the coalescence of the two sides of the urogenital furrow. The cordlike gubernaculum then extends into the bottom of the scrotal pouch.

The final stage of migration of the testicle occurs in the sixth or seventh month, when the gland descends into the inguinal canal. During the eighth intrauterine month the testicle, by vital growth along the gubernaculum, moves along the canal and, in the ninth intrauterine month, normally comes to rest in the scrotum. The remnants of the gubernaculum form a short band which connects the inferior pole of the testicle with the depth of the scrotum, and is designated the *scrotal ligament*. Before descent of the testicle into the scrotal sac to the level it occupies at birth, the vaginal process of peritoneum extends to the depth of the scrotum. This saclike evagination of peritoneum applies itself to the cord and testicle as an incomplete investment, but at no point completely surrounds them. As development advances, only the part of the process applied against the testicle, the *tunica vaginalis testis*, remains patent (Fig. 365, *c*). That part of the vaginal process applied to the spermatic cord between the tunica vaginalis testis and

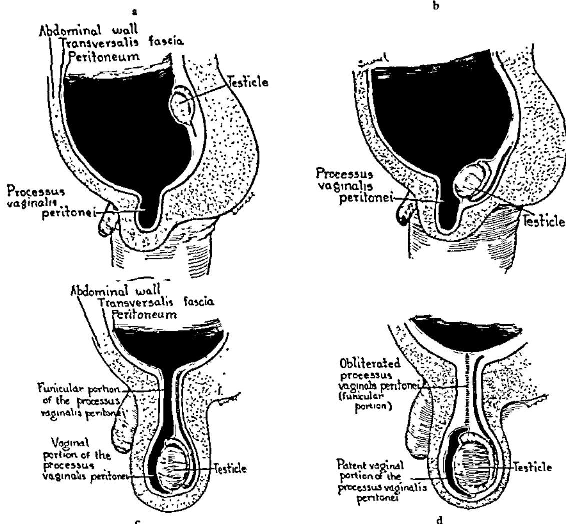


Fig. 365. STAGES IN THE DESCENT OF THE TESTIS, AND IN THE RELATION OF THE ORGAN TO THE VAGINAL PROCESS OF THE PERITONEUM.

a, The testis lies in the lumbar region, at renal level, in the subserous tissue between the transversalis fascia and the peritoneum. *b*, In its descent the testis has reached the brim of the pelvis. *c*, The testis, having reached the base of the scrotum, is partially invested by the visceral layer of the vaginal process (*processus vaginalis peritonaei*); the space of the funicular portion of the peritoneal process, still persistent, is continuous with that of the abdominopelvic cavity. *d*, The funicular part of the vaginal process has been obliterated; the testicular part, however, remains patent.

the abdominal inguinal ring is the funicular portion, which, shortly after birth, loses its patency and becomes a fibrous cord, the *vaginal ligament* (Fig. 365, *d*). The vaginal process of peritoneum may remain patent throughout or in part, constituting developmental irregularities which have a most important bearing on certain forms of hernia and hydrocele.

Patency of the entire process affords a hernial sac of congenital origin, extending from the abdominal inguinal ring to the depth of the scrotum, and accounts for *vaginal hernia*. That part of the process opening into the abdomen may persist and supply the sac of a *funicular hernia*. There may be patency of the funicular part of the process, well into the inguinal canal and into the tunica vaginalis, making possible a *bilocular hydrocele* with an inguinal, as well as a scrotal, pouch. Isolated portions of the process may persist along the spermatic cord when both the superior and inferior parts have become obliterated, and allow formation of *hydroceles* or *cysts* of the *cord*. Longitudinal septa may form in an unobliterated part of the process and give rise to hernias with double or multiple sacs.

The condition of *undescended testicle*, or *cryptorchidism*, exists when the gland is retained in the abdomen or is arrested at some point along the inguinal canal.

WALLS OF THE INGUINAL CANAL. The inguinal canal is not a canal in the ordinary acceptance of the term. In the fetus, and for a varying period after birth, the abdominal wall in the male is traversed by the testicle and the spermatic cord and by the vaginal process of peritoneum. The last is a serous tube continuous with the peritoneal cavity above, and extends to the depth of the scrotum. In the female the abdominal wall is traversed by the round ligament and an outpocketing of peritoneum (canal of Nuck) which accompanies it.

The inguinal canal, then, is an oblique cleft in the inguino-abdominal wall above the mesial half of the inguinal ligament. Its length in the adult varies from 4 to 5 cm. The *inlet* of the canal, the *abdominal inguinal ring*, is located in the transversalis fascia a little above the center of the inguinal ligament. The *outlet*, the *subcutaneous inguinal ring* (Fig. 362), through which the spermatic cord emerges from the abdominal wall, has been described. The superior or deep end of the canal is lateral to the inferior or superficial end, an arrangement which compensates for the weakness in the wall caused by the passage of the spermatic cord. When, as in coughing, the viscera are pressed forcibly against the abdominal inguinal ring, they impinge against the posterior wall of the canal and force it into contact with its anterior wall, almost closing the canal.

The *anterior wall* is the aponeurosis of the external oblique; in the lateral third the fibers of the internal oblique muscle, which arise from the middle third of the inguinal ligament, help in the formation. The lowermost fibers of the internal oblique and, to a less degree, those of the transversus abdominis, as they pass mesially, arch over and form the *upper wall* or *roof* of the canal. They then descend mesially behind it and are commonly regarded as terminating in a so-called inguinal falx (conjoined tendon). The inferior margin of the internal oblique is rendered rather indistinct by the muscle fibers which descend from it along the cord and make up the *cremaster muscle* (Fig. 363). The *floor* of the canal presents a deep gutter, upon which the cord rests. This groove is formed by the fusion of the upper grooved surface of the inguinal ligament (of Poupart) with the lacunar ligament and the transversalis fascia. The *posterior wall* is formed by the transversalis fascia and is, in some persons, strengthened mesially by the inguinal falx, which lies in front of the transversalis fascia and behind the cord (Fig. 364).

ELEMENTS OF THE SPERMATIC SHEATH. In their descent through the inguinal canal, the testicle and the spermatic cord push their way through the transversalis fascia at the abdominal inguinal ring and acquire therefrom an intimate investment, the *internal spermatic* or *infundibuliform fascia*. The testicle then encounters the lower border of the internal oblique muscle, from which it drags down fibers. This partial covering, lying outside the internal spermatic fascia, is the *cremaster muscle* and *fascia*. Stimulation of the cremasteric muscle fibers draws the testis up from the scrotum toward the subcutaneous inguinal ring (cremasteric reflex). Upon passing through the external oblique aponeurosis, the testicle gains its third and outermost covering, the *externa spermatic* or *intercolumnar fascia*. Thus the testicle and that part of the spermatic cord lying outside the inguinal canal acquire three coverings. The mesial part of the cord within the inguinal canal acquires but two investments, while that part behind the internal oblique has only one, the internal spermatic fascia.

SPERMATIC CORD AND THE ROUND LIGAMENT. The SPERMATIC CORD may be examined in the inguinal canal, where it lies beneath the aponeurosis of the external oblique. The constituents of the cord are differentiated readily by splitting the sheath in which are bound together the deferent duct and the numerous blood vessels, lymphatics and nerves.

The *ductus deferens* (*vas*), or duct of the testicle, is a cylindrical, resistant, whitish structure lying posteriorly, surrounded by part of the pampiniform plexus of veins. It has a thick muscular wall and a small lumen, and can be distinguished easily upon palpation of the cord. The *artery of the vas*, derived from the superior vesical artery, is applied closely to the vas and runs a visible, tortuous course upon it. A thickened vas in tuberculous epididymitis indicates extension of the disease to other parts of the genitourinary tract.

The *pampiniform plexus of veins* ascends from the scrotum to the abdominal inguinal ring and there forms the spermatic veins. The varicosity of these veins may become extensive (varicocele). The *internal spermatic artery*, a branch of the abdominal aorta, descends anteriorly in the cord in the midst of the pampiniform plexus. The *external spermatic* (*cre-*

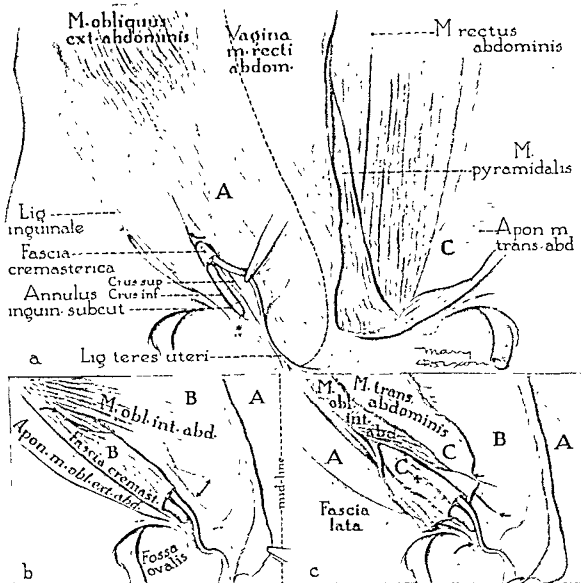


Fig. 366. INGUINAL LAYERS IN THE FEMALE; DEMONSTRATING THE COVERINGS OF THE ROUND LIGAMENT OF THE UTERUS.

a, The round ligament, subcutaneous inguinal ring and related structures. The superficial fascia and the external layer of investing (innominate) fascia have been removed to expose the aponeurosis of the external oblique muscle (right side); at the apex of the aponeurotic cleft (at arrow) the internal layer of investing fascia rests upon cremasteric fascia. The relation of the seam of fusion of the external and internal oblique aponeuroses to the margins of the rectus and pyramidalis muscles is indicated by dotted lines on the specimen's right; the muscles themselves are exposed on the left. The inferior crus is attached to the pubic tubercle (at *)

b, Cremasteric layer, shown by reflecting the external oblique aponeurosis. The internal oblique and its cremasteric derivative have been transected where they pass through the outlet of the canal; within the substance of the fascial tube is imbedded the ilio-inguinal nerve. The arrow at the left marks the point of divergence of parietal and funicular fibers. The arrow at the right points to the margins of an area of fascia bounded by aponeurosis. A hernia adiposa projects beyond the cut end of the tube.

c, Internal spermatic fascia. The internal oblique has been cut and reflected, the cremasteric tube opened to expose the fascial prolongation (at +) derived from the transversus abdominis. The upper arrows mark the margins of the fascial (thinned) area in the internal oblique; the lower arrows indicate the points of attachment of the crura of the external oblique aponeurosis.

Key to lettering: *A*, aponeurosis of the external oblique muscle; *B*, internal oblique layer and its derivative, the "cremasteric" fascia; *C*, transverse abdominal layer and its fascial continuation on the round ligament. (From Anson and Ashley: Quart. Bull., Northwestern Univ. M. School, 15: 69–80, 1941.)

Walls of the Inguinal Canal. The inguinal canal is not a canal in the ordinary acceptance of the term. In the fetus, and for a varying period after birth, the abdominal wall in the male is traversed by the testicle and the spermatic cord and by the vaginal process of peritoneum. The last is a serous tube continuous with the peritoneal cavity above, and extends to the depth of the scrotum. In the female the abdominal wall is traversed by the round ligament and an outpocketing of peritoneum (canal of Nuck) which accompanies it.

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Elements of the Spermatic Sheath. In their descent through the inguinal canal, the testicle and the spermatic cord push their way through the transversalis fascia at the abdominal inguinal ring and acquire therefrom an intimate investment, the *internal spermatic* or *infundibuliform fascia*. The testicle then encounters the lower border of the internal oblique muscle, from which it drags down fibers. This partial covering, lying outside the internal spermatic fascia, is the *cremaster muscle* and *fascia*. Stimulation of the cremasteric muscle fibers draws the testis up from the scrotum toward the subcutaneous inguinal ring (cremasteric reflex). Upon passing through the external oblique aponeurosis, the testicle gains its third and outermost covering, the *external spermatic* or *intercolumnar fascia*. Thus the testicle and that part of the spermatic cord lying outside the inguinal canal acquire three coverings. The mesial part of the cord within the inguinal canal acquires but two investments, while that part behind the internal oblique has only one, the internal spermatic fascia.

Spermatic Cord and the Round Ligament. The spermatic cord may be examined in the inguinal canal, where it lies beneath the aponeurosis of the external oblique. The constituents of the cord are differentiated readily by splitting the sheath in which are bound together the deferent duct and the numerous blood vessels, lymphatics and nerves.

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The *pampiniform plexus of veins* ascends from the scrotum to the abdominal inguinal ring and there forms the spermatic veins. The varicosity of these veins may become extensive (varicocele). The *internal spermatic artery*, a branch of the abdominal aorta, descends anteriorly in the cord in the midst of the pampiniform plexus. The *external spermatic* (*cre-*

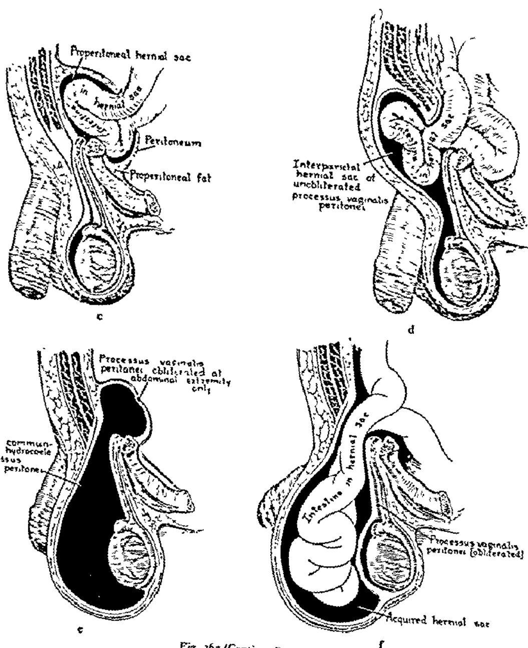


Fig. 367 (Continued)

c, An interparietal, preperitoneal hernia occurs when the herniating mass comes to occupy a serous sacculation formed by the unobliterated proximal segment of the *processus vaginalis peritonaei*. The hernial sac may dissect its way for a considerable distance through the subserous (preperitoneal) tissue, between the peritoneum and the transverse abdominal muscle.

d, A congenital interparietal hernia of inguinal position which occupies the proximal part of the patent vaginal process. Instead of ascending in the preperitoneal (retroperitoneal) connective tissue, the hernia extends upward in the fibrous stratum between the aponeurosis of the external oblique muscle and the internal oblique. Further invasion would result in descent of the hernia into the scrotal portion of the serous sac.

e, An example of congenital bilocular communicating hydrocele. The vaginal process is obliterated only at its abdominal extremity, that is, at the site of the abdominal ring of the inguinal canal.

f, A case of acquired complete indirect inguinal hernia of unusual type. The serous sac is not derived from the *processus vaginalis peritonaei*, but from the parietal peritoneum about the abdominal inguinal ring. The vaginal process, in this instance obliterated, would be found among the constituents of the spermatic cord in the form of a fibrous strand. Theoretically, the vaginal process of the peritoneum could remain patent through any fraction of its extent, thus to appear as a secondary serous prolongation continuous with the parietal peritoneum of the inguinal wall or separate therefrom in the form of a monocular hydrocele.

masteric) artery, derived from the inferior epigastric, is distributed mainly to the elements of the spermatic sheath. It is the chief source of bleeding in manipulation of the spermatic sheath. The *lymphatics* ascend from the testicle to the lumbar and aortic glands, at renal level.

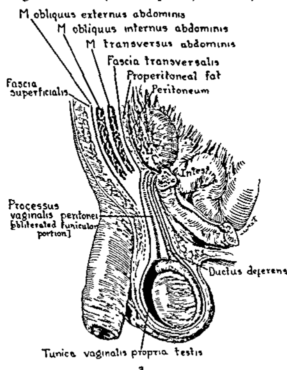
Among the normal elements of the cord is a thin strand, the *vaginal ligament*, a vestige of the vaginal process. A patent vaginal process constitutes the sac for a congenital inguinal hernia, into which class fall almost all indirect hernias. This process, when present, must be considered to be the prime abnormal element within the spermatic sheath (Fig. 369).

The inguinal canal is much smaller in the female than in the male, since it contains only the ROUND LIGAMENT of the uterus (Fig. 366). The subcutaneous inguinal ring is so small as to be difficult to palpate, unless it is enlarged by a hernial protrusion. The round ligament leaves the ring as a bundle of connective tissue strands which, invested successively by parietal layers (Fig. 366) comparable to those of the spermatic cord, finally acquires a finger-shaped prolongation of the superficial fatty pannicle of the inguinal wall (Frontispiece, Part VI). Like the spermatic cord, the round ligament curves around the inferior epigastric vessels, accompanied by the ilio-inguinal nerve and surrounded by a sheathing layer of the transversalis fascia. During fetal life the ligament is accompanied through the abdominal inguinal ring by a finger-like prolongation of peritoneum, the homologue of the vaginal process in the male, which occupies the entire length of the canal. Ordinarily, this diverticulum, the *canal of Nuck*, becomes obliterated by the end of the sixth intrauterine month.

A persistent canal of Nuck explains the presence of cysts and hernias of congenital origin. As a hernia into the canal of Nuck increases in size, it may drag into the sac part of the suspensory ligament of the ovary, which, at its lateral extremity, is not far from the abdominal inguinal ring. This accounts for the fact that the ovary and the distal part of the uterine (fallopian) tube sometimes are found in the hernial sac.

Surgical Considerations

VARIETIES OF INGUINAL HERNIA. *Inguinal* hernias may be divided into two main groups:



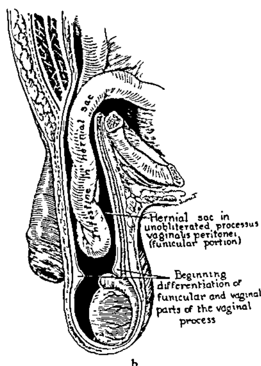


Fig. 367. NORMAL AND HERNIAL ANATOMY IN THE INGUINAL AND SCROTAL REGIONS. DEMONSTRATED BY PARAMEDIAN SECTIONS TO THE LEFT OF THE MIDLINE.

a, The funicular part of the vaginal process of the peritoneum is obliterated normally from the point of its origin at the abdominal inguinal ring to that of the superior border of the testis. The *tunica vaginalis propria* testis is thus the persistent lower end of the fetal peritoneal prolongation which becomes the serous investment of the testis and epididymis.

b, A congenital (indirect) inguinal hernia of the type which occurs when the small intestine or portion of the greater omentum invades a patent funicular portion of the vaginal process of peritoneum. In the instance illustrated, the intestine has descended almost to testicular level.

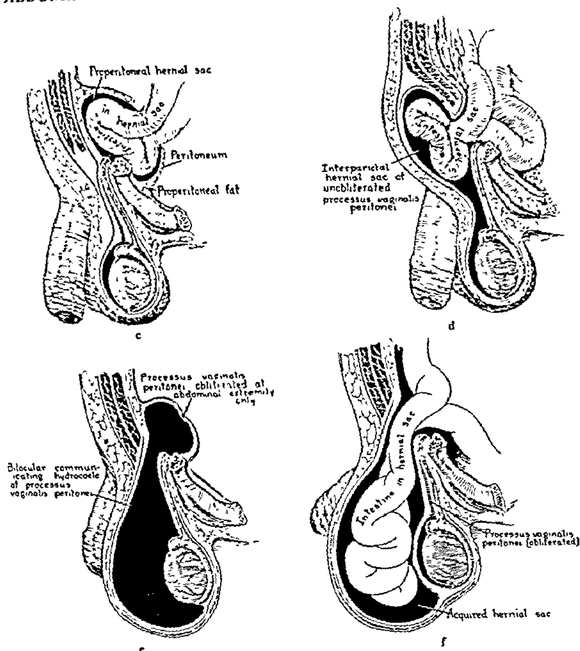


Fig. 367 (Continued)

c, An interparietal, preperitoneal hernia occurs when the herniating mass comes to occupy a serous sacculation formed by the unobliterated proximal segment of the *processus vaginalis peritonaei*. The hernial sac may dissect its way for a considerable distance through the subserous (preperitoneal) tissue, between the peritoneum and the transverse abdominal muscle.

d, A congenital interparietal hernia of inguinal position which occupies the proximal part of the patent vaginal process. Instead of ascending in the preperitoneal (retroperitoneal) connective tissue, the hernia extends upward in the fibrous stratum between the aponeurosis of the external oblique muscle and the internal oblique. Further invasion would result in descent of the hernia into the scrotal portion of the serous sac.

e, An example of congenital bilocular communicating hydrocele. The vaginal process is obliterated only at its abdominal extremity, that is, at the site of the abdominal ring of the inguinal canal.

f, A case of acquired complete indirect inguinal hernia of unusual type. The serous sac is not derived from the *processus vaginalis peritonaei*, but from the parietal peritoneum about the abdominal inguinal ring. The vaginal process, in this instance obliterated, would be found among the constituents of the spermatic cord in the form of a fibrous strand. Theoretically, the vaginal process of the peritoneum could remain patent through any fraction of its extent, thus to appear as a secondary serous prolongation continuous with the parietal peritoneum of the inguinal wall or separate therefrom in the form of a monocular hydrocele.

those which leave the abdomen lateral to the inferior epigastric artery and traverse part, if not all, of the extent of the inguinal canal (indirect, external or oblique); and those which leave the abdomen through the middle inguinal fossa (p. 376) mesial to the inferior epigastric artery and enter the inguinal canal near its outlet (internal or direct). Another classification divides them into congenital and acquired varieties.

By way of introduction to the more detailed discussion of the several varieties, or stages, of herniation through the inguinal canal, the following considerations may be of service.

Normally the *processus vaginalis peritonaei* becomes obliterated from the point of its origin at the abdominal ring of the inguinal canal to that at which it is continuous with the serous (peritoneal) investment of the testis (Fig. 367, *a*).

In some instances, however, the process remains patent through part or all of its length (Figs. 368, 369). When persistent, the process may become occupied by a herniating portion of omentum or intestine. Invasion may be complete, that is, to testicular level (Fig. 367, *b*), or incomplete and interparietal (Fig. 367, *c*, *d*). Obliteration of the process may occur at the proximal extremity only, without occupancy by a hernial protrusion (Fig. 367, *e*); or, while the process is wholly obliterated, the peritoneum adjacent to the abdominal inguinal ring may be carried outward through the inguinal canal and into the scrotum in a course which matches that of the embryonic descent, with the testis, of the vaginal process (Fig. 367, *f*).

CONGENITAL INDIRECT INGUINAL HERNIA; CONGENITAL HYDROCELE. All the congenital varieties of hernia and hydrocele result from developmental defects which occur in connection with failure of obliteration of the vaginal process (p. 376). The term "congenital" does not imply that a hernia is present at birth, but that there is a patent process which will allow the descent of abdominal elements. The process is patent in 50 per cent of infants up to a month after birth. The entrance of abdominal elements into the process, constituting hernia, may not occur for months or even years. The failure of abdominal elements to enter the sac, even though a congenital sac is present, perhaps is accounted for by the obliquity of the inguinal canal.

When the vaginal process remains patent throughout, as in the fetal condition, and the opening of the neck of the sac is sufficiently wide, bowel or omentum may enter the vaginal process and pass down to the depth of the scrotum. This constitutes the VAGINAL INDIRECT INGUINAL HERNIA. The contents of the sac are in contact with the testicle, separated from it only by the visceral layer of the patent tunica vaginalis. The normal elements of the spermatic cord usually lie posterior to the sac and to its medial side; but, in exceptional instances, they are invaginated into the sac, at times appearing as though suspended within it by a serosal duplication.

When the opening at the neck is too small to admit the passage of abdominal contents, serous peritoneal fluid may find its way into the sac and cause an *intermittent vaginal hydrocele*. When the person lies down, the fluid passes back into the general peritoneal cavity. This type of hydrocele may be mistaken for hernia.

In most congenital hernias only the proximal or funicular portion of the vaginal process maintains its fetal connection with the general abdominal cavity. This condition gives rise to the FUNICULAR INDIRECT INGUINAL HERNIA. If the neck of the sac is not large enough to admit abdominal contents, an *intermittent funicular hydrocele* may occur.

In ENCYSTED HERNIAS almost all the vaginal process remains patent, but there is a thin septum of closure at the abdominal inguinal ring. The hernial contents, in making their way into the canal, must invaginate the septum before them, stretching it in some cases to the degree that it bulges downward into the cavity of the tunica vaginalis testis.

INTERPARIETAL HERNIAS are of congenital origin and occur commonly in connection with an incompletely descended testicle, but the testicle may be in the normal position in the scrotum. When the gland is retained within the inguinal canal, the vaginal process almost always is patent, and the hernia occurring within it occupies any of a variety of interparietal positions. The sacs often are bilocular. In the bilocular variety of *properitoneal hernia* the proximal loculus lies between the peritoneum and the transversalis fascia, and the distal loculus usually lies in the inguinal canal. However, the distal loculus may lie between the other layers of the abdominal wall. In *inguinosuperficial hernia* the proximal division of the sac lies between the external oblique

muscle and the skin, sometimes extending nearly to the anterior superior spine. Great care is necessary in making the herniotomy incision, since the sac is superficial. In certain cases the proximal loculus of the sac lies beneath the aponeurosis of the external oblique muscles. It may push the inferior margins of the internal oblique and transversus abdominis muscles superiorly.

The funicular division of the vaginal process may be shut off from the tunica vaginalis testis and from the general peritoneal cavity, and yet remain patent in its intermediate part (along the spermatic cord). Should this sac become distended with fluid, an ENCYSTED HYDROCELE OF THE CORD results. The vaginal process may be obliterated at different levels, so that the patent parts permit the combination of a funicular hernia, an encysted hydrocele of the cord, and a hydrocele of the tunica vaginalis testis. Not infrequently the vaginal process is obliterated only at the abdominal ring, and a large monolocular or bilocular hydrocele of almost the entire vaginal process results.

CONGENITAL INGUINAL HERNIA in the FEMALE rarely is seen in adult life, but is fairly common in infants and young girls. The canal of Nuck remains pervious and forms the sac of a hernial protrusion. The ovary and uterine tube frequently occupy the sac of the hernia. An imperfect closure at any point in the canal of Nuck may lead to an *encysted hydrocele* of the *round ligament*.

SO-CALLED ACQUIRED INDIRECT INGUINAL HERNIA. In exceedingly rare instances, after extraordinary trauma, a hernia, whose sac is

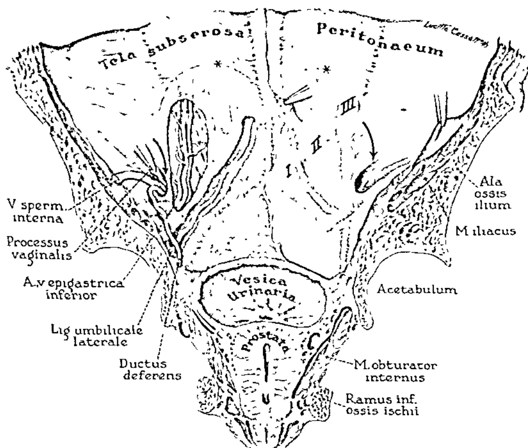


Fig. 368. INTERNAL ASPECT OF THE ANTERIOR ABDOMINAL WALL.

In this coronally sectioned specimen the peritoneum (on the right half) and the retroperitoneal layer (on the left) are shown: At the retroperitoneal level, that is, in the substance of the *tela subserosa*, the following structures are exposed: middle umbilical ligament and lateral umbilical ligament, as these vestigial elements bound the supravesical fovea (at *I*); the inferior epigastric blood vessels, which divide the remaining parietal space into medial and lateral inguinal foveae (at *II* and *III*, respectively); the linea semicircularis (marked by *); the constituents of the spermatic cord, converging upon the abdominal inguinal ring (at the arrow, on each half of the wall). The iliac muscle lines the internal surface of the ala of the ilium; the obturator internus muscle closes the obturator foramen. (From Jennings, Anson and Wright: Surg., Gynec. & Obst., 74: 697–702, 1942.)

not formed at the expense of the funicular part of the vaginal process (which remains tightly obliterated), enters the inguinal canal at the abdominal inguinal ring through the peritoneal dimple or depression which marks the upper limit of obliteration of the funicular process. The sac and its contents make their way down the spermatic cord parallel to the fused funicular process, covered by the spermatic sheath. The sac of this hernia, as opposed to that which occupies the funicular process, is overlaid loosely by the elements of the cord and can be dissected from them easily.

A rare variety of acquired inguinal hernia occurs when there is obliteration of the vaginal process only at the abdominal inguinal ring, below which it remains patent and passes without interruption into the tunica vaginalis testis. An acquired hernial pouch appears behind this and traverses the inguinal canal. This rupture may lead to some confusion at herniotomy, especially when the hernial sac is emptied of its contents at the time of operation. The cavity within the vaginal process, which lies in front of that which contained the hernial contents, passes freely upward into the inguinal canal; when opened, this second space may be mistaken for the true hernial sac, which lies behind, unless it has already been established that the cavity of the vaginal process is closed above at the abdominal ring. The real or acquired hernial sac communicates freely with the abdominal cavity.

It will be serviceable to describe the constituent layers in the order in which they would be encountered by a hernia.

Normally, not the slightest peritoneal protrusion, or even small foveate depression, occurs at the site of the abdominal inguinal ring. In hernial cases the serous sac (Figs. 368,

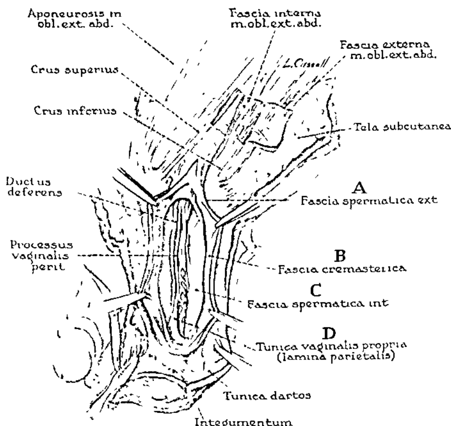


Fig. 369. ABDOMINAL WALL, FROM THE OUTSIDE.

With the funicular continuations of the several inguinal regions, the external oblique is exposed by reflection of the superficial fascia. In a quadrangular area over the superior portion of the intercrural fault, the external investing (innominate) fascia is reflected in order to demonstrate the corresponding internal investing fascia; the two thin fascial layers, conjoined, form the external spermatic fascia. In the scrotal area the external spermatic fascia and the other two funicular coats (cremasteric and internal spermatic fasciae) have been incised and turned aside to show the processus vaginalis and the constituents of the spermatic cord (duct and vessels). The process widens distally to become the tunica vaginalis propria of the testis. An indirect inguinal hernia would occupy, and progressively dilate, this vaginal process of the parietal peritoneum and, in succession outward, the surrounding layers of parietal origin. Lettering as in Fig. 366. (From Morgan and Anson: Quart. Bull., Northwestern Univ. M. School, 16: 20–37, 1942.)

369), once occupied by a hernia, readily dilates the surrounding fascial, or musculofascial, tubes, derived from the inguinal layers (Figs. 370 to 372).

Over the serous sac the preperitoneal (retroperitoneal or subserous) layer is regularly thin, yet usually dissectible as a complete stratum.

The transversus stratum, like the external oblique and internal oblique, is trilaminar. Often the muscle fibers of the transversus layer do not extend as far inferiorly as the abdominal inguinal ring, nor do heavy aponeurotic bands occupy this distal zone. The area of herniation, then, is mainly fascial. The internal, stronger contributing layer is termed the transversalis fascia; the external, weaker element has no special name and is commonly disregarded in standard accounts. On the spermatic cord these layers form the internal spermatic fascia.

The internal oblique layer is also trilaminar, being composed of a musculoaponeurotic portion covered on the outer and inner surfaces by fascia. Together, the lamellae form the cremasteric fascial layer, in which scattered muscle fibers are commonly present. Just as investing fasciae bridge across the intercrural fault in the external oblique, so also the comparable fasciae of the internal oblique stratum extend across the interfascicular spaces, and remain to represent the whole layer in instances in which muscle fibers are wanting.

The funicular part of the layer is, therefore, chiefly fascial, since it constitutes the dilated and saccular covering for the hernial contents.

The inguinal part of the external oblique layer is an aponeurotic continuation of the more proximal, muscular portion of the stratum. It is invested on both surfaces by fasciae, the external one of which is the fascia innominata. As the fibers which make up the inguinal ligament pass to an attachment upon the pubic tubercle, they depart from the neighboring aponeurotic bands which descend, as the superior crus, to an insertion at the pubic symphysis. Between these diverging columns is a triangular intercrural cleft, the apex of which may reach the muscular part of the external oblique layer at the level of the anterior superior iliac spine. Only the external and internal investing fasciae bridge the intercolumnar, aponeurotic gap. In this gap the two fascial layers are applied to each other back to back. At the medial extremity of the triangular cleft, and just cranial to the pubic tubercle, the spermatic cord passes beyond the plane of the parietal layers and receives its investment of fascia. There the two fascial lamellae fuse to form the thin external spermatic fascia, in which a varying number of intercrural fibers occur.

In its course through the abdominal wall the spermatic cord carries about it, in funicular manner, strata prolonged from the parietal layers. On its external surface the transversus layer becomes tubular about the spermatic cord in the plane of the abdominal wall, the tube resembling a curved pipe emerging from a flat surface. The internal oblique stratum does not invest the cord tightly at its proximal end, but surrounds the cord as a broad infundibuliform investment. There is no duplication to form an "intermediate inguinal ring"; therefore the mouth of the funnel is usually more than twice the size of the abdominal inguinal ring. After acquiring its cremasteric coat, somewhat below the level of pubic tubercle and inguinal ligament, the cord passes forward beyond the plane of the external oblique layer, carrying with it the external spermatic fascia in tubular form.

Direct Inguinal Hernia. A direct or internal inguinal hernia enters the inguinal canal through Hesselbach's triangle, a little lateral to or opposite the subcutaneous inguinal ring. It passes directly through or lateral to the inguinal falx (conjoined tendon), and its subsequent course in the inguinal canal is the same as that of an indirect hernia (Fig. 373). An important difference between direct and indirect hernias is their relation to the inferior epigastric artery. The neck of the sac of an indirect hernia lies lateral to the artery, while that of a direct hernia is mesial to it. Direct hernia is observed most frequently in adult life when, from various causes, a heavy strain is thrown upon the abdominal wall, especially when there is a diminution of muscle tone. The lax muscles yield easily, and the inguino-abdominal region bulges forward characteristically. Certain diseases predispose to rupture because of the frequent sudden increase in intra-abdominal pressure which they entail. Among these may be mentioned chronic bronchitis, prostatic enlargement and urethral stricture. Direct hernia is of slow development, and its beginning is indicated by an exaggeration of the internal or the middle inguinal fossa, usually the middle. After increasing sufficiently in size to occupy the inguinal canal, the hernia

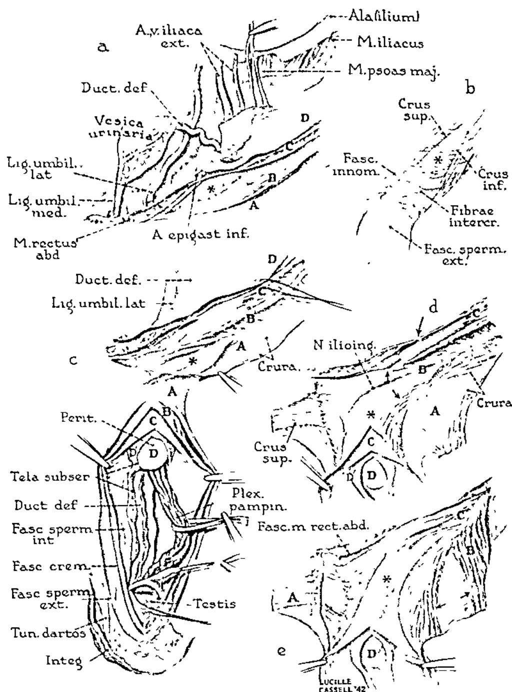


Fig. 370. INGUINAL AND FUNICULAR LAYERS IN A SPECIMEN WITH AN INDIRECT INGUINAL HERNIA (LEFT HALF OF SPECIMEN ILLUSTRATED).

For these successive dissections the specimen was transected above the iliac alae, and the abdominal wall sectioned transversely. The skin and superficial fasciae were removed, and the external oblique layer was separated from the internal oblique. This separation was continued where the layers became funicular about the spermatic cord. The peritoneum and preperitoneal layer were then freed from the internal aspect of the transversus layer. This line of separation was carried into the tube of the internal spermatic fascia.

a, The peritoneal aspect of the inguinal wall viewed from above and behind. The genitofemoral nerve is held by forceps. By removing the peritoneum (*D*) in the area around the abdominal inguinal ring, the oblique course and relations of the inguinal canal (indicated by an asterisk) are demonstrated. *b*, The area of the subcutaneous inguinal ring, seen from the outside. The dilated processus vaginalis (at the asterisk) is here covered superficially by the external spermatic fascia (derived from the innominate fascia of the external oblique layer), in which are lodged the intercrural fibers. The fault in the aponeurosis of the external oblique is triangular, and is bounded by columns (superior and inferior crura). *c*, The external oblique and internal oblique have been drawn forward The layers of the spermatic cord have been incised successively to expose the constituents of the cord and their investments. The retroperitoneal layer forms a definite sheath for the internal spermatic artery, pampiniform plexus and ductus deferens (sheath opened to show the contents).

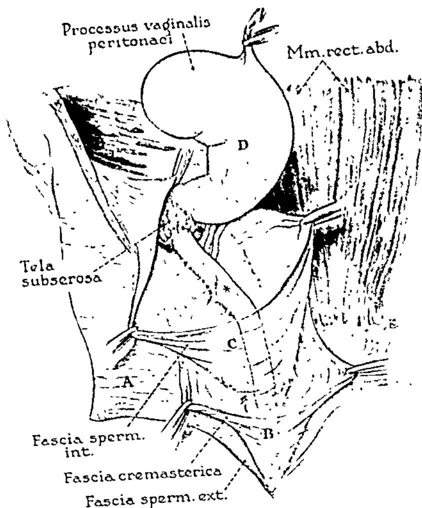


Fig. 371. LAYERS COVERING THE SEROUS SAC OF AN INDIRECT INGUINAL HERNIA, OPENED AND RETRACTED; DEMONSTRATING THEIR CONTINUITIES AND INTERRELATIONSHIPS.

The outermost parietal investment (*A*) of the hernial mass is the external spermatic (intercrural, intercolumnar or innominate) fascia, carried downward into the scrotum from the margins of the columns (or crura) of the subcutaneous inguinal ring (compare Figs. 370 and 372). The intermediate coat (*B*) is the cremasteric, in which muscle fascicles of the internal oblique may be wholly wanting. The third and innermost layer (at *C*) is the internal spermatic (infundibuliform) fascia, derived from the transversalis fascia; only in rare instances does this stratum contain fascicles from the transverse abdominal muscle.

Both the spermatic cord (at *) and the *processus vaginalis peritonaei* (at *D*) are lodged in the fatty subserous layer (retroperitoneal connective tissue), which, in the dissection pictured, has been removed except in the area of the abdominal inguinal ring. The serous sac (peritoneum) is dilated by the contained hernial mass; in the figure it is elevated by a tag of tissue through which it was anchored to the inner surface of the dartos tunic. (From Anson, Morgan and McVay: Quart. Bull., Northwestern Univ. M. School, 16: 128–41, 1942.)

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d, The external oblique layer has been incised vertically and then turned aside to expose the broad, funnel-like portion of the internal oblique stratum (indicated at the asterisk). The upper arrow indicates the point at which the transversalis fascia sends off a lamella to invest the rectus muscle. The smaller arrows point to margins of the muscular portion of the internal oblique; the lower fibers are prolonged upon the cord as cremasteric muscle fibers. Except where they are present, the cremasteric layer is completely fascial. In the reflected portion of the external oblique the aponeurotic crura and the intercrural fascia (at *A*) are evident. *e*, The transversus stratum is shown by incising and reflecting the overlying portion of the internal oblique layer. By continuing the incision into the scrotum the internal spermatic fascia (at the asterisk) is exposed. Distally, the latter envelope has been opened to show the retroperitoneal connective tissue and the peritoneal (serous) sac (*D*). The margins of the fascial portion of the internal oblique layer (*B*) are indicated by arrows (compare *d*).

Key: *A*, external oblique; *B*, internal oblique; *C*, transversus abdominis; *D'*, retroperitoneal tissue; *D*, peritoneum. (From Anson, Morgan and McVay: Quart. Bull., Northwestern Univ. M. School, 16: 128–41, 1942.)

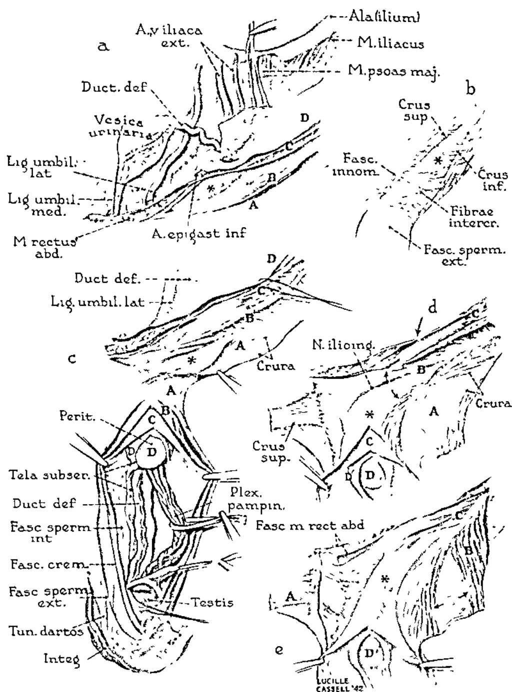


Fig. 370. INGUINAL AND FUNICULAR LAYERS IN A SPECIMEN WITH AN INDIRECT INGUINAL HERNIA (LEFT HALF OF SPECIMEN ILLUSTRATED).

For these successive dissections the specimen was transected above the iliac alae, and the abdominal wall sectioned transversely. The skin and superficial fasciae were removed, and the external oblique layer was separated from the internal oblique. This separation was continued where the layers became funicular about the spermatic cord. The peritoneum and preperitoneal layer were then freed from the internal aspect of the transversus layer. This line of separation was carried into the tube of the internal spermatic fascia.

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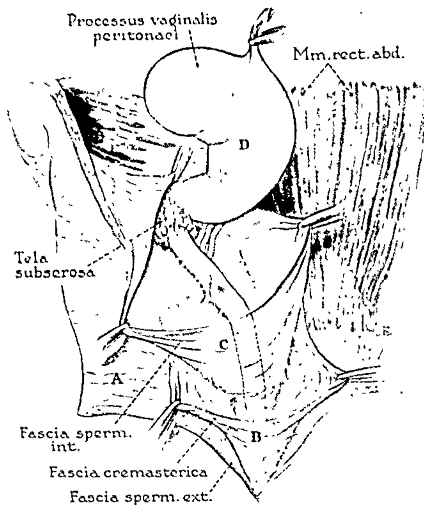


Fig. 371. LAYERS COVERING THE SEROUS SAC OF AN INDIRECT INGUINAL HERNIA, OPENED AND RETRACTED; DEMONSTRATING THEIR CONTINUITIES AND INTERRELATIONSHIPS.

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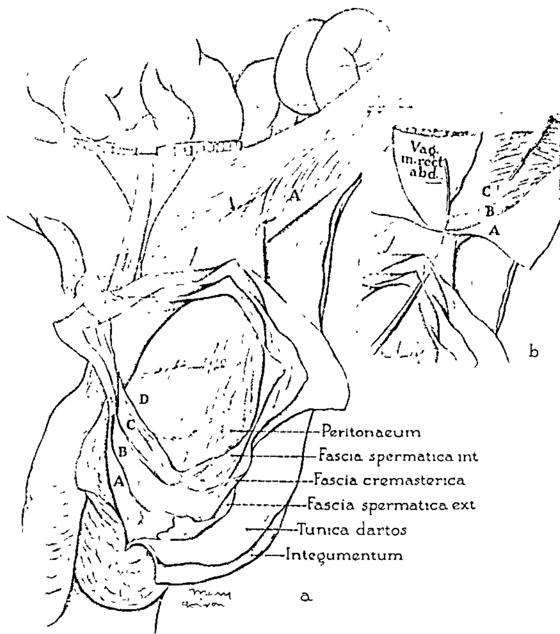


Fig. 372. INGUINAL AND SCROTAL LAYERS IN A SPECIMEN WITH LARGE INDIRECT INGUINAL HERNIA.

a, The skin and superficial fascia have been reflected to expose the outer layer of investing fascia (innominate fascia) of external oblique aponeurosis; on the scrotum the parietal layers have been incised and reflected in serial succession; only the subserous layer is not separately dissectible The crura (at arrows) of the subcutaneous inguinal ring are spread apart by the herniating mass (compare Figs. 369 and 370, *b*) *b*, The 3 inguinal strata from which the scrotal layers are derived. A probe is placed between the cremaster and the internal spermatic fascia. Lettering in both figures corresponds to that in Figures 366 and 371. (From Ashley and Anson: Quart. Bull., Northwestern Univ. M. School, 15: 114–21, 1941.)

emerges through the external ring and forms a protrusion above the pubic spine, a *bubonocele.* The volume increases by degrees until it occupies and distends the scrotum on the same side, constituting a *complete direct inguinal* (*scrotal*) *hernia.*

If the hernia has been present for some time, it will have altered profoundly the length and direction of the inguinal canal. Because of the traction which it exercises, it may become so large as to contain the greater part of the small intestine and a part of the large bowel. The inguinal rings approximate each other more and more until the canal is reduced to a short, wide passage leading the exploring finger directly backward through the abdominal wall.

In long-standing inguinal hernias some difficulty may be experienced in deciding which variety is present. The inferior epigastric

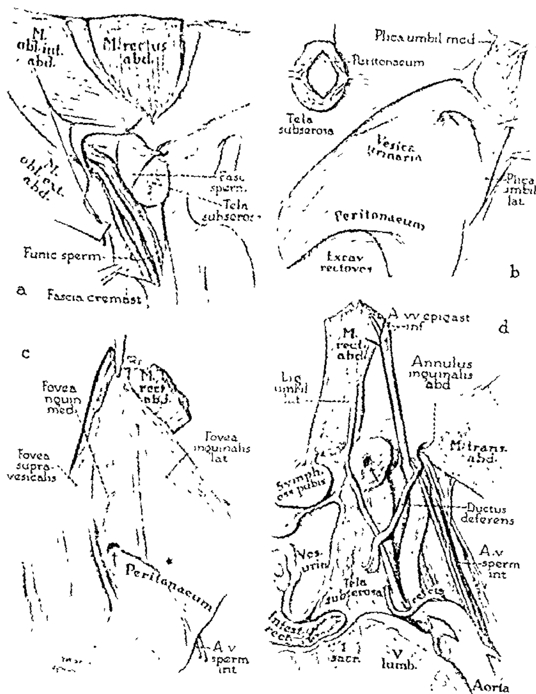


Fig. 373. DIRECT (DIVERTICULAR) INGUINAL HERNIA IN MALE SPECIMENS.

a, The cremaster, internal spermatic fascia and spermatic cord in relation to the hernial protrusion. *b*, The hernial sac opened. The orifice in relation to the peritoneal elevations.

c and *d*, Hernial anatomy in a second specimen. *c*, Hernial orifice and peritoneal foveae. *d*, Related retroperitoneal structures in the hemisected pelvis.

In *a* the internal spermatic fasciae overs the proximal part of the lipomatous enlargement in the preperitoneal layer. The external oblique aponeurosis has been reflected; the aponeuroticofascial part of the internal oblique has been incised obliquely, the lower flap of cremasteric layer then being retracted. In *b* the opened peritoneal process is shown within the lipomatous lobule of the preperitoneal layer. In *d* the peritoneum has been removed except in a small area around the orifice of the sac. Arrows point to peritoneal diverticula of direct hernias. In *c* the site of the subjacent abdominal inguinal ring is indicated by a star. (From Ashley, Anson and Beaton: Quart. Bull., Northwestern Univ. M. School, 15: 192–204, 1941.)

artery in an old indirect rupture is deflected medial to its normal course, and may be found curving upward and medially close to the lateral edge of the rectus muscle. If a long-standing hernia becomes strangulated, it is advisable to incise the constricting neck in an upward and medial direction from the neck of the sac to avoid injuring the inferior epigastric vessels. If a direct hernia is mistaken for an indirect hernia, and the neck of the sac is incised in a lateral direction, these vessels will be injured. If an old indirect hernia is mistaken for a direct hernia, and the constricting neck is cut in a mesial direction, the same accident will occur.

In a *primary direct hernia of the bladder* a part of the viscus, usually that not covered by peritoneum, or a bladder diverticulum, may be extruded, and with it a large quantity of prevesical fat, constituting practically a "lipoma," so that the true condition of affairs may be unsuspected. As more of the bladder becomes involved, the part covered by peritoneum will be included, and with it an extension of peritoneum from behind that part of the bladder which first became extruded. Part of the bladder covered by peritoneum, therefore, will lie within the sac, while the extraperitoneal portion will be devoid of a sac.

Herniation of the bladder may be *secondary* when an inguinal rupture, usually of the direct type, already is present. As the hernial sac increases at the expense of the parietal peritoneum about the abdominal aperture, the bladder gradually is included. In young children much of the bladder lies in the abdomen above the level of the symphysis, and may extend laterally almost to the abdominal inguinal ring, so that it is possible in the course of herniotomy to injure the viscus. Traction upon the hernial sac in an attempt to ligate its neck high up may draw a part of the bladder wall into close proximity of the abdominal ring, or even into the ring itself, where it may be injured in the placing of the sutures transfixing the sac. This awkward accident has led to urinary infiltration in the deeper parts of the wound, and to fistulae discharging into the hernial region.

DIFFERENTIAL DIAGNOSIS OF OBLIQUE OR INDIRECT AND DIRECT INGUINAL HERNIA. The differential diagnosis as to whether an inguinal hernia is indirect or direct should be made preoperatively, and can be decided correctly in about 85 per cent of cases. The anatomic feature of the indirect sac emerging from the abdomen lateral to the deep epigastric artery, and the direct medial to it, is of poor clinical value because the artery can rarely be felt. Helpful findings, however, are listed on page 391.

INGUINAL HERNIOTOMY. The two main reasons for subjecting hernias to operative treatment are the need for radical cure and the relief of strangulation. The two essential procedures in operative treatment are removal of the sac after carefully reducing its contents and ligating it at its neck, and reconstruction of the inguinal canal (Figs. 374, 375).

The operation which has long seemed suitable to these requirements is that devised by Bassini, or one of its numerous modifications. The features of the Bassini operation are briefly as follows (Fig. 375): An incision is developed along the line bisecting the angle formed by the inguinal ligament and the lateral margin of the rectus muscle, beginning a little above the abdominal ring and extending to the pubic spine. The aponeurosis of the external oblique is exposed after division of the superficial fasciae (as described on page 355) and of the superficial epigastric and external pudendal arteries lying between them. At the mesial portion of the wound the spermatic cord is exposed, and the subcutaneous inguinal ring is defined. Beginning at the apex of the ring, the aponeurosis of the external oblique is incised as far as the abdominal ring.

If the hernia is *indirect*, the sac must be sought in combination with the cord and

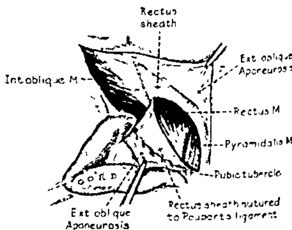


Fig. 374. THE USE OF RECTUS SHEATH IN THE REPAIR OF INGUINAL HERNIA.

A flap of the anterior rectus sheath has been reflected laterally and sutured to Poupart's ligament. (From Davis: Arch. Surg., 68: 557–69, 1954.)

	Indirect Inguinal Hernia	Direct Inguinal Hernia
Frequency by sex	In males inguinal hernia is indirect in 70-80% In females inguinal hernia is indirect in 98%	In males 20-30% are direct In females only 2% are direct
Age	Infancy up to 30 years	Usually after 30
Shape	Oval or pear-shaped	Globular
Extent	Often scrotal	Almost never scrotal
Side	Unilateral in 75%	Bilateral in over 60%
Reducibility	Sometimes irreducible	Virtually always reducible
Relation to cord	In front and to outer side of cord	Above and to inner side of cord
Direction	Descends obliquely	Comes straight out through external ring
External ring	Not enlarged until hernia is complete	Always enlarged
Inguinal canal	Posterior wall is firm with finger in canal	Posterior wall is deficient; finger passes straight back through abdominal wall
Epigastric artery	Never palpable	Never palpable

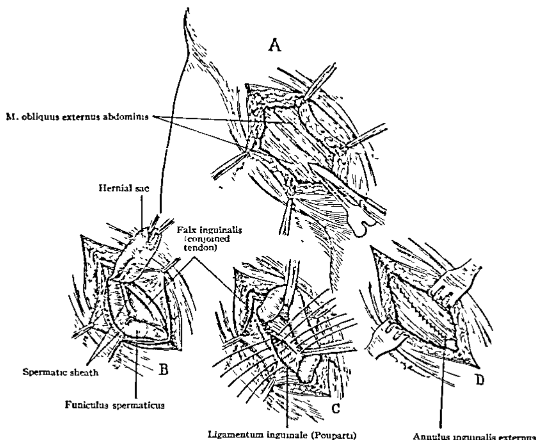


Fig. 375. BASSINI OPERATION FOR INGUINAL HERNIA.

A, Oblique inguinal skin incision, division of subcutaneous fat and superficial fasciae of Camper and Scarpa (p. 355) and of the superficial epigastric and external pudendal arteries lying between them. The aponeurosis of the external oblique muscle is divided in the direction of its fibers, from the subcutaneous ring to the abdominal ring, care being taken not to injure the iliohypogastric and ilio-inguinal nerves. *B*, The spermatic sheath, which consists of the cremasteric and internal spermatic fasciae, has been incised longitudinally. The hernial sac is located and dissected from the cord structures. The sac is usually opened and any contents returned to the abdominal cavity before this dissection. *C*, The sac has been ligated high at its neck (flush with the peritoneal cavity) and the distal portion excised. Reconstruction of the inguinal canal is begun by suturing the inferior border of the internal oblique and transversus abdominis muscles to the shelving margin of the inguinal ligament. The close relations of the femoral vessels deep to the inguinal ligament must be kept in mind when these sutures are inserted. The cord is then laid down upon this line of sutures, which transplants it one layer anteriorly from its former position. *D*, External oblique fascia closed over the cord, allowing for a snug but not too tight external ring.

A transverse inguinal incision (Fig. 358, *J*) is well suited to this operation and heals with an inconspicuous scar.

within its sheath. Forceps are applied to the margins of the sheath, which consists of the cremasteric and the internal spermatic (infundibuliform) fascia, and it is separated longitudinally, exposing the elements of the cord. The sac is separated from the deferent duct and the pampiniform plexus, and its neck is isolated carefully, ligated, and divided at the point of exit from the abdominal inguinal ring. The distal portion of the sac is then excised. Excessive traction upon the sac is to be avoided, lest the bladder be drawn into the canal. The stump of the sac is allowed to retract flush with the abdominal peritoneum, or it may be drawn superiorly beneath the musculature of the roof of the canal, and sutured there. If the sac is of the complete (vaginal) type, the inferior part is ligated by purse-string suture to form a closed *tunica vaginalis testis.*

Reconstruction of the inguinal canal strengthens the hernial region and minimizes recurrence. The procedure contemplates closure of the gap between the inferior border of the internal oblique and transversus abdominis muscles superiorly, and the inguinal ligament inferiorly. After the cord has been freed from its sheath and retracted superiorly or inferiorly out of the wound, the inferior border of these muscles is brought down and sutured to the shelving margin of the inguinal ligament. The close relations of the femoral vessels deep to the inguinal ligament must be borne in mind when these sutures are inserted. Care is taken not to constrict the spermatic cord where it emerges from the abdominal ring. The cord is laid upon the sutured muscles (transplanted), the incision in the aponeurosis of the external oblique muscle is sutured, and the external abdominal ring, if unduly large, is reduced to dimensions which will not constrict the emerging cord.

The incision for *direct inguinal hernia* is the same as that for the indirect variety, but the coverings of the sac are different. The spermatic sheath, with its cremasteric and infundibuliform coverings and the cord, lies to the

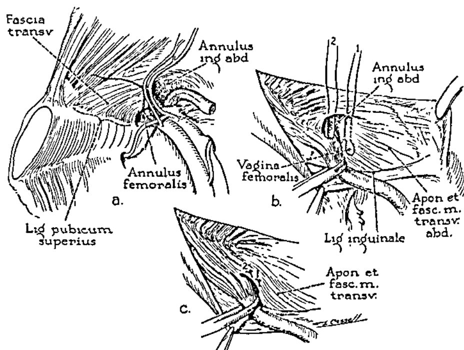


Fig. 376. REPAIR OF SMALL INDIRECT INGUINAL HERNIA.

a, The inguinal region, posterior view, anatomic dissection. The peritoneum, preperitoneal connective tissue and the hernial sac have been removed to show that in such instances the inguinal region is normal except for slight dilatation of the abdominal inguinal ring.

b, The inguinal region, anterior view. The hernial sac has been ligated, excised, and retracted out of view. Two sutures have been placed. The first brings together the transversalis fascia and the anterior layer of the femoral sheath; thereby the slightly dilated abdominal inguinal ring is reduced to normal size. The second suture transfixes the fasciae of the cord to the transversalis fascia, thus preventing subsequent protrusion of lobules of preperitoneal fat.

c, Concluding the reparative steps, the sutures (at 1 and 2) have been tied and the abdominal inguinal ring closed. The external oblique aponeurosis will be closed over the spermatic cord. (From McVay and Anson: Surg., Gynec. & Obst., 88: 473-85, 1949.)

lateral side of the hernial bulge. The rupture, bearing outward through Hesselbach's triangle, is covered by a thin expansion from the inguinal falx, and a sheath which, though derived from the transversalis fascia, is free and distinct from the internal spermatic (infundibuliform) fascia of the cord. The sac usually has a broader neck and is much more difficult to resect than that of the indirect variety. The Bassini technique in the reconstruction of the new posterior wall for the cord is similar to that devised for indirect hernia. An additional strengthening layer for Hesselbach's triangle may be added by turning down a flap of the anterior sheath of the rectus muscle (Fig. 374), or even fibers from the lateral margin of the rectus muscle itself, and suturing them to the shelving edge of the inguinal ligament.

A modification of the Bassini technique (*Ferguson operation*), more applicable in indirect than in direct hernia, allows the cord to remain *in situ* against the original back wall of the canal after the sac has been excised. A new anterior wall is made for the cord by suturing the inferior margin of the internal oblique and transversus abdominis muscles and their inguinal falx to the inguinal ligament anterior to the nontransplanted cord. In this procedure

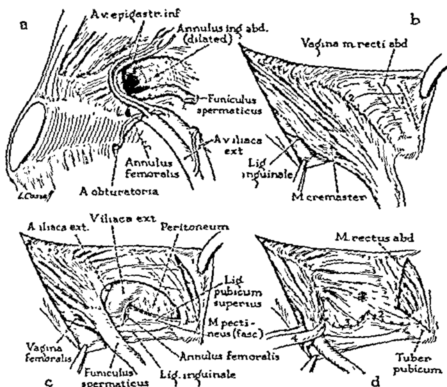


Fig. 377. REPAIR OF LARGE INDIRECT INGUINAL HERNIA.

a, The inguinal region, posterior view. The peritoneum, preperitoneal connective tissue and the hernial sac have been removed to demonstrate the dilated abdominal inguinal ring and the displaced inferior epigastric vessels.

b, The same specimen, anterior view. The spermatic cord is enlarged by the contained hernial sac. The relaxing incision is made just lateral to this line of fusion (dotted line at 1). A second incision is made between the strong portion of the posterior wall and the area attenuated by the enlarged abdominal ring (dotted line at 2).

c, In continuing the procedure, the incisions (represented by the numbered lines in *b*) have been made, and the thinned portion of the posterior wall has been completely excised. The femoral sheath and superior pubic ligament are exposed. The investments of the spermatic cord have been trimmed to normal size by excising the now redundant fascial coverings. The new, strong, lower margin of the transversus abdominis aponeurosis (posterior wall) will be sutured to the superior pubic ligament, in the area from the pubic tubercle to the femoral vein. From this latter point the transversalis fascia will be sutured to the anterior wall of the femoral sheath (dotted line indicating the line of suture).

d, In concluding the procedure, the strong posterior wall has been sutured to the superior pubic ligament (at 2) and the anterior layer of the femoral sheath (at 3). The spermatic cord (at 4) has been drawn farther lateralward to show the line of suture as it extends upward to, and closes, the abdominal inguinal ring. The relaxing incision (at 1) is now an open triangular defect protected behind by the lower end of the rectus muscle and its tendon of pubic origin. The lateral margin, retracted and angular, is usually sutured to the underlying tendon of the rectus abdominis. The spermatic cord is replaced against the posterior wall, and the external oblique aponeurosis is closed over it. (From McVay and Anson: Surg., Gynec. & Obst., 88: 473-85, 1949.)

within its sheath. Forceps are applied to the margins of the sheath, which consists of the cremasteric and the internal spermatic (infundibuliform) fascia, and it is separated longitudinally, exposing the elements of the cord. The sac is separated from the deferent duct and the pampiniform plexus, and its neck is isolated carefully, ligated, and divided at the point of exit from the abdominal inguinal ring. The distal portion of the sac is then excised. Excessive traction upon the sac is to be avoided, lest the bladder be drawn into the canal. The stump of the sac is allowed to retract flush with the abdominal peritoneum, or it may be drawn superiorly beneath the musculature of the roof of the canal, and sutured there. If the sac is of the complete (vaginal) type, the inferior part is ligated by purse-string suture to form a closed *tunica vaginalis testis*.

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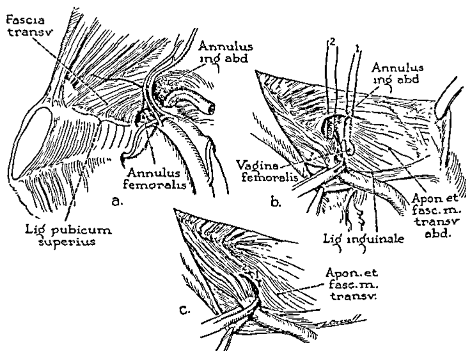


Fig. 376. REPAIR OF SMALL INDIRECT INGUINAL HERNIA.

a, The inguinal region, posterior view, anatomic dissection. The peritoneum, preperitoneal connective tissue and the hernial sac have been removed to show that in such instances the inguinal region is normal except for slight dilatation of the abdominal inguinal ring.

b, The inguinal region, anterior view. The hernial sac has been ligated, excised, and retracted out of view. Two sutures have been placed. The first brings together the transversalis fascia and the anterior layer of the femoral sheath; thereby the slightly dilated abdominal inguinal ring is reduced to normal size. The second suture transfixes the fasciae of the cord to the transversalis fascia, thus preventing subsequent protrusion of lobules of preperitoneal fat.

c, Concluding the reparative steps, the sutures (at 1 and 2) have been tied and the abdominal inguinal ring closed. The external oblique aponeurosis will be closed over the spermatic cord. (From McVay and Anson: Surg., Gynec. & Obst., 88: 473–85, 1949.)

ligament. Identification of the sheath for the femoral artery and vein, therefore, represents nothing more than a precautionary measure to safeguard these large vessels; mobilization of the inguinal ligament is a maneuver made solely to expose them.

Once the saccular protrusion in the internal oblique layer is exposed, whether the hernia be indirect (Figs. 376, 377) or direct (Fig. 378), repair consists in strengthening the immediate area of defect in the aponeurotic or muscular wall.

In indirect inguinal hernia the thinned and weakened portions of the layers are first excised, as they form the inguinal wall above and medial to the abdominal (deep) inguinal ring and as they are carried outward therefrom upon the spermatic cord. Second, the new lower border of the layers (consisting of tissue stronger than that excised) is sutured to the superior pubic ligament in the area between the pubic tubercle and the femoral vein.

In repairing a direct inguinal hernia the procedure is similar in all main aspects (Fig. 378). However, since the area of weakness is limited to the wall, removal of tissue does not extend to the coverings of the spermatic cord.

Repair of a femoral hernia may be accomplished by use of a fundamentally similar technique. However, since the defect is situated caudal to the line of the inguinal ligament, the aponeurosis of the transverse abdominal muscle is given new anchorage, by suturing to the heavy fascial investment of the pectineus muscle, in an area just in front of the superior pubic ligament.

In each of the three operations a relaxing incision in the rectus sheath, made opposite the area of repair, will serve to reduce traction on the inguinal wall in the region of the hernioplasty.

Ryan has restored the use of living fascial sutures, as advocated by McArthur, while retaining the technique of Bassini; and Burton* uses Gallie's method of procuring such material from the thigh.

* Surg., Gynec. & Obst., 77:530–33, 534–8, 1943.

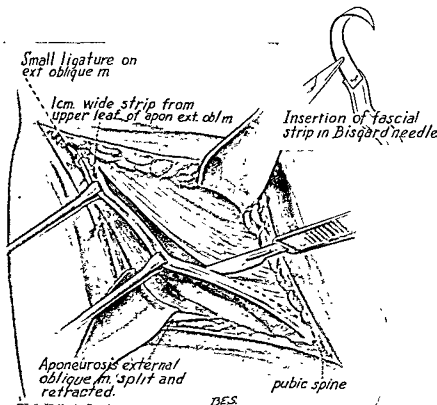


Fig. 379. REPAIR OF INGUINAL HERNIA BY THE USE OF LIVING FASCIAL SUTURES.
Showing the method of stripping the fascial material from the aponeurosis of the external oblique muscle. Insert: Method of anchoring the suture in the needle. (From Ryan: Surg., Gynec. & Obst., 77: 534–8, 1943.)

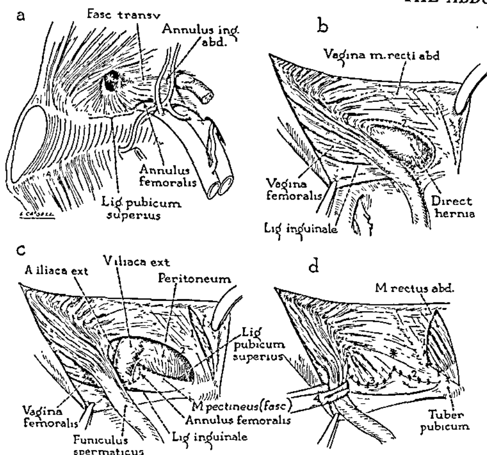


Fig. 378. REPAIR OF DIRECT INGUINAL HERNIA OF PEDUNCULATED TYPE.

a, The inguinal region, posterior view. The peritoneum, retroperitoneal connective tissue and the hernial sac have been removed to demonstrate the defect in the inguinal wall. The abdominal inguinal ring is normal in size, and the inferior epigastric vessels are not displaced.

b, The same specimen, anterior view, showing the bulge in the inguinal wall. The spermatic cord contains no processus vaginalis. The first incision (at dotted line 1) is the relaxing incision in the rectus sheath, made just lateral to the line of fusion of the external oblique and internal oblique aponeuroses. The second incision (at dotted line 2) follows the upper margin of the attenuated posterior wall, and is the superior boundary of that portion to be excised.

c, In continuing the procedure, the relaxing incision (at 1) has been made, and through its slightly retracted borders the underlying rectus muscle can be seen. The succeeding incision (at 2) has also been made; additionally, all the attenuated portion of the inguinal wall has been excised to expose the superior pubic ligament and the margin of the femoral sheath. The excision of aponeurotic fibers and fascia extends to the abdominal inguinal ring. The hernial sac has been removed and the spermatic cord retracted farther lateralward. The posterior inguinal wall, along its newly made margin, will be sutured to the superior pubic ligament and to the femoral sheath (along the dotted lines).

d, In concluding the surgical steps, the strong superior and medial portion of the transversus layer has now been drawn downward and sutured to the superior pubic ligament (at 2) and to the anterior femoral sheath (at 3). The spermatic cord has been pulled even farther lateralward (at 4) to demonstrate that the suture line extends far enough laterally to close snugly the abdominal inguinal ring. As before, the spermatic cord is replaced against the newly made posterior wall, and the external oblique aponeurosis is closed over it. (From McVay and Anson: Surg., Gynec. & Obst., 88: 473–85, 1949.)

the elements of the cord are not disturbed and therefore are less traumatized. For a direct hernia or a large indirect hernia, it has the disadvantage of not allowing complete closure of the new wall at the pubic spine, where space must be left for the cord to emerge.

Another procedure contemplates transplantation of the cord entirely out of the inguinal canal (*original Halsted operation*) into a position between the skin and the aponeurosis of the external oblique. A stronger wall is formed posterior to the cord by approximation to the inguinal ligament, of not only the internal oblique and transversus abdominis muscles, but also the aponeurosis of the external oblique.

In another type of hernial surgery, described by McVay and Anson, the inguinal ligament plays no part whatsoever in the actual repair (Figs. 376 to 378); it is merely freed in order to reveal clearly the underlying femoral sheath and to open the route to the superior pubic

(Fig. 380). Closure is carried lateralward, as in the Bassini method, to the site of emergence of the spermatic cord at the abdominal inguinal ring.

It is a common experience in surgery that, in operating upon recurrent hernias, the muscle may be firmly united to the inguinal (Poupart's) ligament through part of the course of the suture line, yet separated therefrom through the rest of its course. Failure in healing is believed to be due to incomplete removal of areolar tissue from the structures sutured together. However, good union may be obtained directly between muscle and fascia, that is, when areolar tissue has been carefully removed from both (Fig. 381). Therefore, as might be expected, fascial (or aponeurotic or tendinous) grafts likewise become readily incorporated into the healing area in hernial repair. Because the constituent collagen fibrils of the connective tissues are inert intercellular substances, fascia may be preserved in alcohol without changing the properties of these collagen fibrils in any way, either chemically or physically. In catgut or kangaroo tendon the fibrils are changed both chemically and physically—chemically by the reagents added, and physically by heating. Yet when alcohol-preserved fascia is implanted in a host, it "takes" just as well as living fascia (Koontz). The preserved graft is repopulated by living cells which invade it from the tissues of the host; it also becomes vascularized by the ingrowth of blood vessels. As a matter of fact, the same process takes place when a "living" graft is transplanted. In this graft the vascularization is lost in the process of transplantation, and the cells die. Therefore the living graft must be repopu-

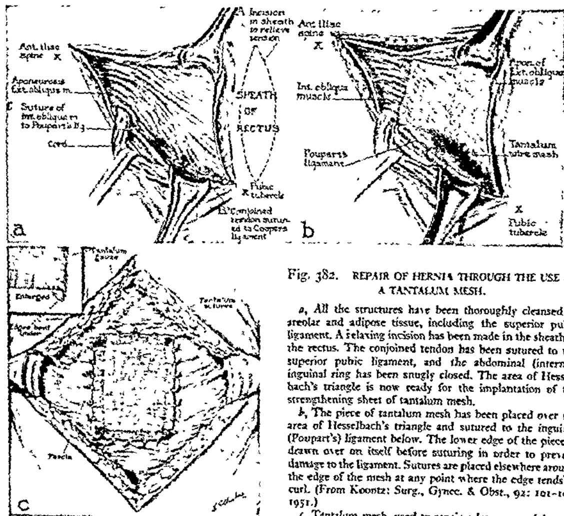


Fig. 382. REPAIR OF HERNIA THROUGH THE USE OF A TANTALUM MESH.

a, All the structures have been thoroughly cleansed of areolar and adipose tissue, including the superior pubic ligament. A relaxing incision has been made in the sheath of the rectus. The conjoined tendon has been sutured to the superior pubic ligament, and the abdominal (internal) inguinal ring has been snugly closed. The area of Hesselbach's triangle is now ready for the implantation of the strengthening sheet of tantalum mesh.

b, The piece of tantalum mesh has been placed over the area of Hesselbach's triangle and sutured to the inguinal (Poupart's) ligament below. The lower edge of the piece is drawn over on itself before suturing in order to prevent damage to the ligament. Sutures are placed elsewhere around the edge of the mesh at any point where the edge tends to curl. (From Koontz: Surg., Gynec. & Obst., 92: 101–104, 1951.)

c, Tantalum mesh, used to repair a large ventral hernia; a technique especially successful in repair of large defects in obese patients whose fasciae are weakened by an infiltration of fat. (From Koontz: South. M.J., 41: 214–17, 1948.)

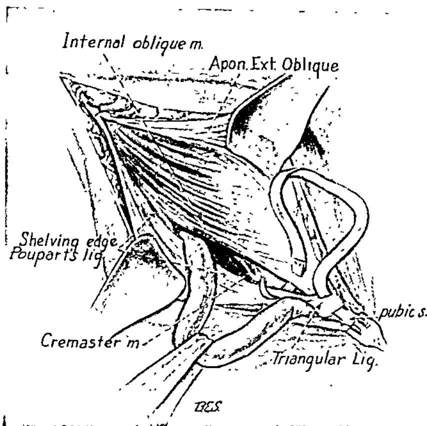


Fig. 380. REPAIR BY FASCIAL SUTURES (CONTINUED).

Showing the way in which the first bite is taken through the medial, aponeurotic portion of the internal oblique layer and the adjacent inguinal (Poupart's) ligament. (From Ryan: Surg., Gynec. & Obst., 77: 534–8, 1943.)

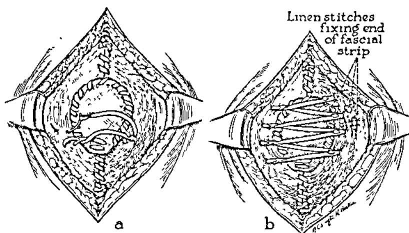


Fig. 381. REPAIR OF A LARGE POSTOPERATIVE HERNIA.

a, The edges of the defect have been closed as far as possible with a running stitch of preserved ox fascia lata. The remainder of the defect has been closed by suturing in a free graft of preserved ox fascia lata, a strip of the same materal being used as a continuous suture. The reinforcement stitch has been started and left loose, showing the details of the lock stitches (Gallie technique).

b, The reinforcement lacework of preserved ox fascia strips overlying the free graft of the same material. The terminal end of the fascia strip is sutured in place with linen, instead of being split and tied into a knot as Gallie recommended. (From Koontz: Arch. Surg., 26: 500–509, 1933)

In the procedure followed by Ryan, the fascial suture is obtained by taking a strip from the aponeurosis of the external oblique in the local area just above the inguinal ligament (Fig. 379). Then, by using the excised aponeurotic ribbon in place of catgut or silk, the autogenous suture anchors the internal oblique to the shelving edge of the inguinal ligament

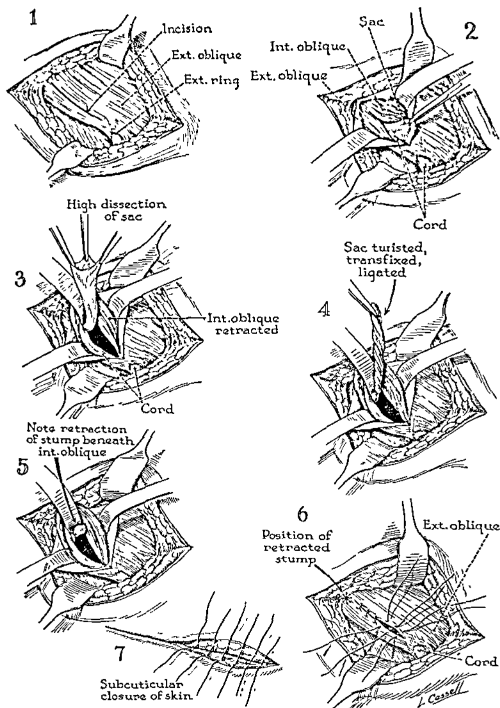


Fig. 385. REPAIR OF INDIRECT INGUINAL HERNIA IN THE INFANT.

1, Incision in the aponeurosis of the external oblique muscle, stopping short of the subcutaneous inguinal ring. 2, Exposure of the hernial sac beneath the internal oblique layer. 3, Mobilization of the sac after retraction of the internal oblique. 4, Essential maneuver of twisting the sac before high ligation. 5, Replacement of remnant stump beneath the internal oblique layer. 6, Coaptation of the margins of the external oblique aponeurosis over the site of the amputated saccular stump (site of the latter at the asterisk). 7, Closure of the superficial fascia and skin. (From Potts, Riker and Lewis: Ann. Surg., 132: 566–76, 1950.)

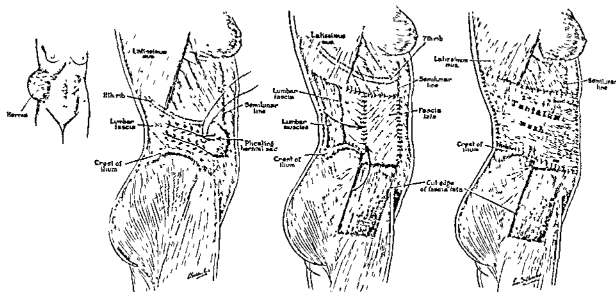


Fig. 383. REPAIR OF MASSIVE INCISIONAL LUMBAR HERNIA.

Inset, Pictorial record of the great size of lumbar hernias capable of repair by use of fascial grafts and tantalum mesh. Drawings of procedure picture 3 stages in repair of the massive lumbar herniation. *First*, Showing plication of the hernial sac after it has been dissected free of the skin and subcutaneous fatty tissue (muscular and aponeurotic tissue being atrophic or wholly wanting in the area above the crest of the ilium). *Second*, Demonstrating the manner in which a piece of fascia lata is reflected upward and sutured to the fascia over the ribs superiorly and to the rectus sheath anteriorly, and the way in which a plaque of lumbar fascia, reflected forward, has been sutured to the fascia lata and to the fascia of the thorax. *Third*, Illustrating the last step in repair, in which the entire operative area has been reinforced with a piece of tantalum gauze. (From Koontz: Surg., Gynec. & Obst., 101: 119–21, 1955.)

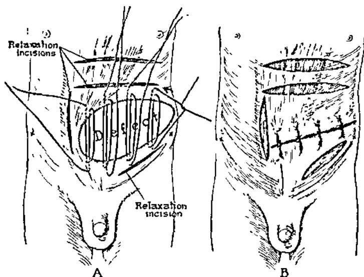


Fig. 384. ANTERIOR ABDOMINAL WALL FASCIAL RELAXING INCISIONS IN REPAIR OF LARGE HERNIAS, INCISIONAL OR ABOUT COLOSTOMIES AND ILEOSTOMIES.

A, Relaxing incisions permit approximation of the fascial margins of the defect. These incisions are made as follows: longitudinally in the rectus sheath of the opposite side; transversely in the fascia above the level of the defect; obliquely in the aponeurosis of the external oblique muscle below the level of the defect (thus near the inguinal ligament). In the stage pictured the far-and-near tension sutures have been placed, but not tied. *B*, Condition after the sutures have been tied. The importance of the relaxing incisions is demonstrated by the degree of gaping before these sutures were closed with 000 tantalum wire. (From Koontz: J.A.M.A., 162: 1156–7, 1956.)

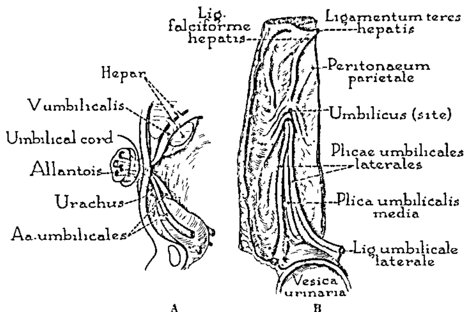


Fig. 386. UMBILICAL REGION IN THE EMBRYO AND IN THE ADULT (AFTER CULLEN).

A, Umbilical and related structures in the human embryo; sagittal view of a reconstruction. As a constituent of the placental circulation, the umbilical vein passes through the umbilical cord to the navel, and thence in the free edge of the falciform ligament to a fossa on the inferior surface of the liver. The umbilical arteries ascend from pelvic source, passing forward and upward to the anterior abdominal wall. Reaching the navel, the arteries occupy the umbilical cord with the corresponding vein and the urachus, the latter structure being an elongate tube continuous with the apex of the urinary bladder. In the umbilical cord the urachus becomes continuous, in turn, with the allantoic stalk.

B, Adult ligamentous remnants of the umbilical blood vessels and of the urachus, and the serous folds caused by their presence on the internal aspect of the anterior abdominal wall. The obliterated umbilical vein occupies a fold of peritoneum, the falciform ligament of the liver, which, arising from the upper part of the anterior abdominal wall, runs to the umbilical incisura of the liver. Below the level of the umbilicus the urachus, persisting as a ligamentous strand, lifts the peritoneum in the median plane to produce a middle umbilical fold. Over the umbilical arteries the peritoneum projects, to each side of the midline, as a lateral umbilical fold. These *plicae*, together with lesser serous elevations over the functional inferior epigastric vessels, form boundaries of *foveae* on the internal aspect of the wall.

same interval, has increased greatly in size and is filled with amniotic fluid in which the fetus is suspended.

Since the abdominal portion of the alimentary canal increases in length much more rapidly than does the coelomic or body cavity, much of the gut extrudes itself through the large patent defect in the abdominal wall and lies in the umbilical cord. As the body cavity becomes large enough to contain the abdominal viscera, the intestinal loop to which the vitello-intestinal duct is attached returns to the body cavity. Later, when the body walls are formed, this narrow duct runs along the cord and connects the intestine with its shriveled yolk sac. The abdominal walls, in their ventral growth, gradually close off the body cavity until, at birth, no trace of the yolk stalk remains. Should all the bowel contents of the umbilical cord fail to return to the abdomen, or should a part of the cord remain open, maintaining a communication with the abdominal cavity, a *hernia into the cord* results (Fig. 387).

Under normal conditions the vitello-intestinal duct, omphalomesenteric vessels, and urachus atrophy into fibrous cords. In consequence of this process, the umbilical ring, which is traversed by these structures, is reduced to a small orifice. After birth, blood no longer circulates in the vessels of the cord, and a small umbilical crust remains where the cord has been ligated and cut. This heals rapidly and epithelializes without suppuration. As healing progresses, fibrous changes take place within the vessels and urachus and draw the scar against the circumference of the umbilical ring. The force of the retraction of the umbilical vein draws the scar against the uppermost circumference of the ring, but the adhesion thus formed is less dense than that resulting from the adhesion of the scar to the inferior

lated with cells from the host and must be revascularized. According to Koontz, the procedure eliminates the necessity of obtaining fascia lata strips from the thigh, a method which occasions an additional operation on the patient. Large postoperative hernias have also been repaired with large sheets of alcohol-preserved fascia lata.

Although not universally accepted, successful repair has been obtained through the use of tantalum mesh, which is nonirritating to tissues (Koontz). Normal fibrous tissues grow through the interstices of the mesh, which becomes thoroughly surrounded and infiltrated by strong fibrous tissue.

The tantalum mesh has been used clinically in the following three ways: to close defects in the abdominal wall in which the fascial edges could barely be approximated (Fig. 383); to reinforce weak abdominal walls after the repair of ventral hernias in which the fascial edges could barely be approximated, and in which surrounding fascia was so weak that a cure could not have been expected by the simple closure; and to reinforce the area of Hesselbach's triangle in repairing inguinal hernias with large defects and weak surrounding structures (Fig. 382, *a*, *b*). Large direct hernias, large indirect scrotal hernias of long standing, and recurrent hernias are the types prone to have such poor tissues (Fig. 382, *c*).

One advantage claimed for tantalum over fascia and such nonabsorbable materials as silk, cotton and linen, is its resistance to infection. Fascial grafts in the presence of infection slough out; infected wounds containing silk, cotton or linen will form persistent sinus tracts, which will not close until the offending sutures are removed. Tantalum, while occasionally sloughing, often heals without sinus-tract formation.

The use of relaxing fascial incisions is a sound surgical principle in aiding the repair of massive ventral or incisional herniae and those which occur about colostomies and ileostomies (Figs. 383, 384).

In contrast to the problem presented by large ventral hernias in obese adults is the structurally simpler surgical task of treating typical indirect inguinal hernias in infants and children, when the cause is not muscular weakness, but failure in obliteration of the vaginal process.

After exposure of the hernial sac, and without opening the subcutaneous inguinal ring, the sac is twisted, transfixed high, and tied snugly (Fig. 385). The excess peritoneum is cut away and the incision closed.

UMBILICAL REGION

Definition and Boundaries. The umbilical region occupies the central portion of the anterolateral abdominal wall. It derives its surgical interest from the occurrence of a special form of hernia (umbilical) and a number of congenital anomalies related to the fetal circulation, the vitello-intestinal duct and the urachus.

Development of the Umbilical Region. The surgical anatomy of the region is incomplete without brief reference to its development, which is given with a view toward rendering intelligible the abnormal conditions found at the umbilicus, and associated conditions within the abdominal cavity, the result of arrested or imperfect development in fetal life.

In the early human embryo the alimentary canal communicates freely with the yolk sac by the *vitello-intestinal duct.* Caudal to this communication, the alimentary tube throws out a diverticulum, the *allantois.* The cavity of the allantois is continuous with that of the *urachus*, which grows out anteriorly into the *umbilical pedicle.* This pedicle is the means of attachment of the embryo to the chorion, and contains the vessels which supply the fetus. At this period the lining of the true body cavity, or *coelom*, is directly continuous with the lining of the outside body cavity, or *exocoelom.* These cavities communicate broadly with one another. As the embryo enlarges, its ventral enclosed area, bounded by the edge of the amnion, becomes relatively smaller. The tubular structure contained within the ventral enclosed area is the *umbilical cord.* The cord encloses the yolk stalk, allantois, and the fetal blood vessels which pass to and from the placenta (Fig. 386). Thenceforth the umbilical cord connects the embryo to that part of the outer fetal membrane which constitutes the fetal surface of the placenta, the *chorion.*

By the end of the third month the body walls have closed in except at the umbilical ring, to the periphery of which the cord is adherent. The amnion invests the cord externally and is continuous with the skin of the abdomen. The amniotic cavity, during the

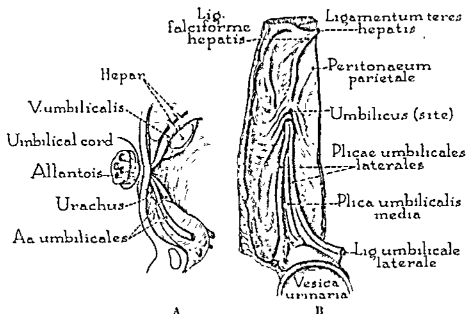


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Under normal conditions the vitello-intestinal duct, omphalomesenteric vessels, and urachus atrophy into fibrous cords. In consequence of this process, the umbilical ring, which is traversed by these structures, is reduced to a small orifice. After birth, blood no longer circulates in the vessels of the cord, and a small umbilical crust remains where the cord has been ligated and cut. This heals rapidly and epithelializes without suppuration. As healing progresses, fibrous changes take place within the vessels and urachus and draw the scar against the circumference of the umbilical ring. The force of the retraction of the umbilical vein draws the scar against the uppermost circumference of the ring, but the adhesion thus formed is less dense than that resulting from the adhesion of the scar to the inferior

contour of the ring, caused by the inferior pull of the two obliterated umbilical arteries and the urachus. Thus it occurs that, in the superior part of the ring, there is an area of lesser fusion where the subcutaneous tissue is almost in contact with the extraperitoneal fat. This area is the site of election for the development of umbilical hernia. In the infant the umbilicus bulges slightly forward; in the adult it usually is retracted. Retraction is explained by the fact that the urachus and obliterated umbilical arteries form unyielding cords incapable of elongating as the abdominal walls and pelvis continue to grow.

Slight hernias commonly bulge through the umbilicus in the newborn, but prompt reduction, followed by suitable and persistent padding, assures such healing as will insure a resistant abdominal wall.

SURFACE ANATOMY. Between the umbilical papilla and the contour of the ring is a circular or elliptical depression, about which is a superficial bulge caused by the presence of fat in the subcutaneous tissues. The papilla usually is a little elevated, very irregular, and surmounted by the scar. At the ring the fat is absent, so that the thin skin is fused directly to the ring margins, the adhesion being particularly dense over the inferior contour of the ring. Upon reducing an umbilical hernia, the finger invaginates the abdominal cavity, readily palpating the fibrous contour of the ring. After multiple pregnancies, or with ascites, the ring may be dilated and enlarged.

FIBRO-APONEUROTIC UMBILICAL RING. The fibrous contour of the ring, formed within the linea alba by the abdominal aponeuroses, constitutes the framework for the region and contains the umbilical debris overlaid by skin. When the ring is examined on its deep aspect after the peritoneal layer has been stripped away, two sets of semicircular fibers with their opposed concavities are exposed. The fusion of the umbilical remains to the ring contour at first is soft and unresistant; toward the end of the first year the papilla presents a definite resistance closing the orifice firmly.

Surgical Considerations

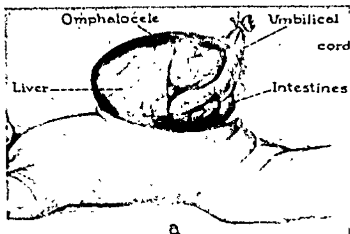
It is customary to describe three distinct forms of umbilical hernia: hernia into the umbilical cord, infantile, and acquired.

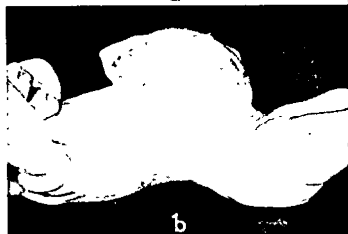
HERNIA INTO THE UMBILICAL CORD. Hernia into the cord may be explained on the basis of the failure of the abdominal muscles on the two sides to approximate and unite properly at the midline, because of the intervention of viscera which should have receded into the abdominal cavity during the later period of intrauterine life. The hernia which results is present at birth. In other words, instead of an umbilical cord emerging from a small opening, there is no proper umbilicus, only a broad, funnel-shaped defect in the central part of the abdominal wall through which the viscera protrude into the umbilical cord.

A segment of intestine may be found in the cord, the umbilical vessels either spreading over it or being pushed to one side. The protruding part may be a loop of normally developed intestine, which may be replaced with little difficulty. In large hernias the liver and spleen may lie within the cord, together with the major part of the bowel. Sometimes the rupture contains the remains of the vitello-intestinal duct, which is connected by its proximal or basal end with the small intestine within the abdomen, Meckel's diverticulum. Occasionally the original umbilical loop of intestine may fail to withdraw itself into the abdomen and may remain within the cord, perhaps connected at its apex with the narrowed stalk of the yolk sac.

The covering of these large hernias consists of the peritoneum and, externally, the amnion, but no skin. The sac is extremely thin, easily becomes infected, and is prone to rupture in the first hours or days of life. Treatment at one time consisted in opening the sac, attempting to replace the viscera, and closing the abdominal wall. This was often impossible, and frequently, when accomplished, so increased intra-abdominal pressure as seriously to impair breathing, obstruct the venous circulation, and close down on the gastrointestinal tract lumen. Gross devised an ingenious two-stage repair (Fig. 387) that obviates much of these difficulties and greatly lowers the mortality. At the first stage, which should be done in the immediate early hours of life, the protruding mass is covered with skin; months later the second stage consists in repairing the hernia.

INFANTILE UMBILICAL HERNIA. Infantile umbilical hernia, as distinguished from hernia into the umbilical cord, appears within a few days or weeks after the stump of the cord has dropped off (Figs. 388, 389). Infantile hernia is covered with true skin and not with gelatinous







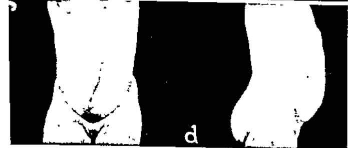


Fig. 387. TWO-STAGE PROCEDURE FOR REPAIR OF OMPHALOCELE.

a, Original lesion in 10-hour old infant. The extruded mass was somewhat larger than the general abdominal cavity. Reduction was impossible; hence the stump of the umbilical cord was excised and the omphalocele sac covered with skin mobilized by wide undercutting down to the pubis, up to the breast area, and well around the flanks. There was no respiratory embarrassment, and the postoperative course was good. *b*, Two weeks after the first stage. *c*, Nine months after the first stage. It was noted that tension in the hernial mass began to lessen at 7 months, that there was considerable laxity at 8 months, and that at the time of this photograph the intestines and liver could be replaced into the abdomen. The final repair was relatively easy. *d*, Two months after completion of the second-stage operation. (From Gross: Surgery, 24: 277-92, 1948.)

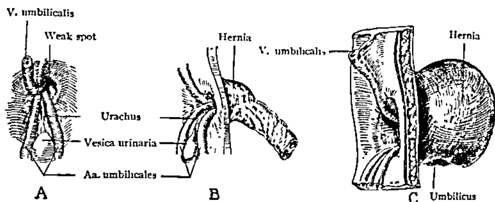


Fig. 388. DIAGRAM OF THE UMBILICAL RING TO SHOW ITS SIGNIFICANCE IN THE DEVELOPMENT OF UMBILICAL HERNIA.

A, Dissection of the umbilical ring in an 8 months' human embryo, viewed from within; the peritoneum and extraperitoneal connective tissue have been removed, and there is exposed a funnel-shaped opening above and to the right of the umbilical arteries. The umbilical vein lies to the left of this weak spot. The umbilical arteries are the strongest structures within the ring, and a hernial protrusion usually occurs above or to one side of them. *B*, Side view of the umbilical ring, showing the usual position of the small hernial protrusion often seen in the newborn. *C*, Larger hernia which represents a later stage of the same type. Note how the umbilicus lies at the inferior part of the hernial protrusion.

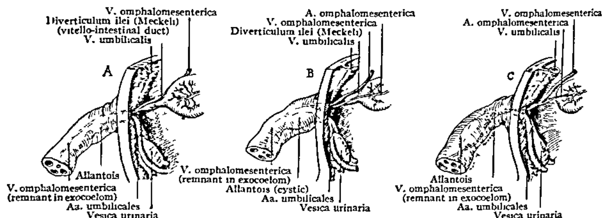


Fig. 389. DIAGRAM TO SHOW FAILURE OF EMBRYONIC STRUCTURES IN THE UMBILICAL REGION TO REGRESS NORMALLY.

A, Persistent omphalomesenteric vein and a patent vitello-intestinal duct. *B*, Persistent omphalomesenteric vessels and a diverticulum of the ileum (Meckel), as well as a cystic allantois in the umbilical cord. *C*, Persistent omphalomesenteric vessels

cord tissue as is a hernia into the cord. As a rule, a hernia in an infant remains a small, rounded protrusion, rarely larger than a walnut, appearing in the superior rather than in the inferior margin of the umbilical ring. It is easily reducible, and becomes prominent when the child cries or coughs; it is symptomless, its strangulation is rare, and increase in size is uncommon.

The cause of the protrusion is a weakness in the adhesion between the scarred remains in the cord and the umbilical ring (p. 402). When the abdomen is large and distended, the overstretched linea alba has a tendency to widen, and the gap may be so extensive that a median bulge appears between the recti when the child cries. In such cases infantile umbilical hernia not uncommonly exists. These hernias tend to undergo spontaneous cure, but if this does not occur by three or four years of age, it is a simple matter through a transverse incision (Fig. 358, *E*) to excise the small sac and close the rectus fascia. The umbilicus should not be excised in children, since they may be the butt of jibes by their playmates because of its absence.

Acquired Umbilical Hernia. The hernial protrusion of an acquired umbilical hernia makes its appearance at some period remote from the closure of the umbilical ring. In order for the condition to supervene, it is obvious that the cicatricial tissue closing the ring must yield gradually. This is most likely to take place at the upper margin of the ring, because

the scar between the debris of the cord and the ring is not as strong there as at the inferior margin. As predisposing factors, there may be mentioned the excessive stretching of the abdominal wall which occurs with pregnancy, hard labor, ascites and obesity. Deposition of fat in the superior part of the ring also may weaken it.

Adult hernia, as contrasted with the infantile variety, does not tend to spontaneous recession, but rather to steady increase in size. In adult hernia the sac always is thin, and its coverings may be so stretched and attenuated as to make it appear that the hernial contents lie just under the skin. If the contents be intestine, peristaltic movement may be visible. The contents often consist of a mass of omentum, with perhaps part of the transverse colon or small intestine. These hernias often are lobulated in outline, the lobulation apparently being caused by the irregular manner in which the hernial sac expands. By following the lines of least resistance, the sac insinuates itself between the resisting bands of fascia which connect the skin to the subjacent aponeurosis. The loculi or sacculations may be seen by opening the sac and turning aside the contents which may be adherent to it. As the hernia usually makes its exit immediately below the superior border of the ring and not at its center, the umbilical scar usually is at some distance to one side or inferior to the bulk of the protruding mass. Contrasted with infrequent strangulation in the infantile hernia is the frequent strangulation in the adult hernia.

Radical Cure of Acquired Umbilical Hernia. On the anterior abdominal wall herniation may occur at the umbilicus (Figs. 388, 389), through the linea alba or along the semilunar line (Fig. 390). With no sharp differentiation, umbilical hernias may be grouped as small or large. The small ones may be not over 2 cm. in diameter, but often cause some pain because of caught, tender mesentery. The large hernias may be enormous and hang halfway to the knees. The sac frequently has a small neck, but tends to dissect laterally and downward in the subcutaneous tissue. The sac frequently becomes multilocular and may contain portions of the colon and several loops of small intestine.

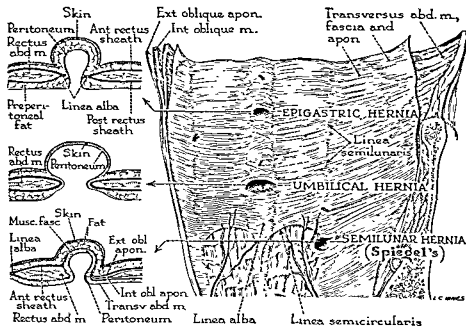


Fig. 390. SITES OF HERNIAS OF THE ANTERIOR ABDOMINAL WALL, SEEN IN POSTERIOR VIEW, AND THE PARIETAL INVESTMENTS OF EACH, SHOWN BY TRANSVERSE SECTIONS.

Right, The points of herniation through the linea alba, and the position of an extrusion lateral to the rectus muscle, along the linea semilunaris. *Left*, The coverings of the hernias which differ in their relation to superficial fatty tissue and subjacent aponeurosis. At epigastric level a fatty pannicle intervenes between the integument and the peritoneum, but is wanting at the umbilicus. Along the semilunar line, below the level of the semicircular line, the aponeurotic plate, produced by fusion of the aponeuroses of the 3 abdominal muscles, contributes a covering to the hernia; it is situated between the peritoneum (and retroperitoneal tissue) and the fatty layer of superficial fascia. (From McVay in Davis: Christopher's Textbook of Surgery.)

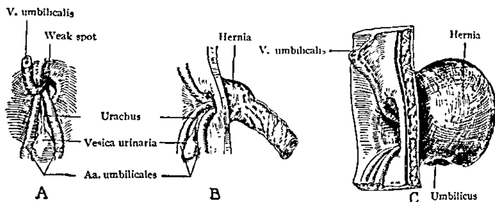


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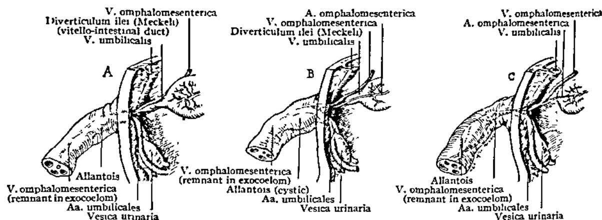


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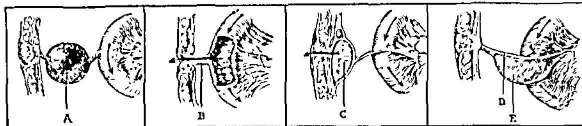


Fig. 392. VARIETIES OF OMPHALOMESENTERIC PATHOLOGY.

A, Cyst resulting from torsion of omphalomesenteric duct. *B*, Patent omphalomesenteric duct. *C*, Cyst of the umbilicus, result of a remnant of the omphalomesenteric duct. *D*, Fibrous cord formed from the omphalomesenteric vessels. *E*, Meckel's diverticulum. (Cullen.)

diverticulum may create an intestinal obstruction by twisting itself around an adjacent coil of intestine, or by becoming adherent to some neighboring part, the abdominal wall, intestine or mesentery, thus forming a cord about which a coil of intestine may fold and become constricted. The *distal end of the diverticulum may be continued into a fibrous cord* and may maintain its connection with the intestine and umbilicus. This is likely to bring about an intestinal strangulation and obstruction. The duct may *remain open throughout its length* and constitute one of the varieties of umbilical fistula in which the constant escape of feces and mucus constitutes a great source of annoyance. Occasionally, certain forms of cystic adenoma are found which apparently have risen from *vestiges of the duct* in the *umbilical region*.

Congenital Defects in the Allantois. In the fetus the allantois consists of an abdominal and an extra-abdominal portion. After birth the abdominal portion, between the urinary bladder and the umbilicus, shrinks and is converted into a fibrous cord, the *urachus*. The extra-abdominal portion lies among the contents of the umbilical cord. The urachus may be patent throughout, with a consequent fistulous opening at the umbilicus through which urine escapes. Closure of the urachus at the two ends sometimes occurs, the intervening portion remaining patent, a condition which may cause a cystic tumor of considerable size. The cyst is extraperitoneal.

Posterolateral Abdominal Wall (Lumbar or Iliocostal Region)

Surgical interest in the lumbar or iliocostal region arises from the fact that surgical access to the kidneys and the proximal portion of the ureters is offered therein.

Definition, Boundaries and Landmarks. Superficially, the posterolateral abdominal wall comprises the quadrilateral area between the lowermost ribs, the iliac crest, the vertebral column, and a vertical line erected at the anterior superior iliac spine. Deeply, the region takes in the parietal peritoneum and the retroperitoneal space, which includes the lumbar and iliac fossae. The lumbar and iliac fossae are described in the section devoted to the retroperitoneal structures of the abdomen. The *landmarks are the lumbar vertebral column, the* iliac crest, the eleventh and twelfth (floating) ribs, and the depression lateral to the bulky mass of the sacrospinalis muscle.

Superficial Structures. The superficial fascia is disposed in two layers, between which an excessive quantity of loculated fatty tissue is deposited. This loose tissue frequently is the seat of extensive suppuration which gravitates down to, but does not extend into, the corresponding tissue of the anterolateral wall. The arteries, veins and nerves are small and of no surgical import.

Lumbodorsal (Lumbar) Fascia. It is convenient to consider the three divisions of the lumbodorsal fascia as fusing lateral to the sacrospinalis and quadratus lumborum muscles into a broad aponeurosis which extends anteriorly as the transversus abdominis muscle (p. 356). The *posterior* and by far the thickest *layer* of this fascia originates over the lumbar spinous processes and the supraspinous ligaments and gives a stout dorsal investment to the sacrospinalis muscle (Figs. 393, 394). This lamella is covered by the latissimus dorsi and the serratus posterior inferior muscles, to which it gives origin.

The *middle layer* of fascia is attached to the posterior surfaces and tips of the lumbar transverse processes; it lies in front of the sacrospinalis muscle and behind the quadratus lum-

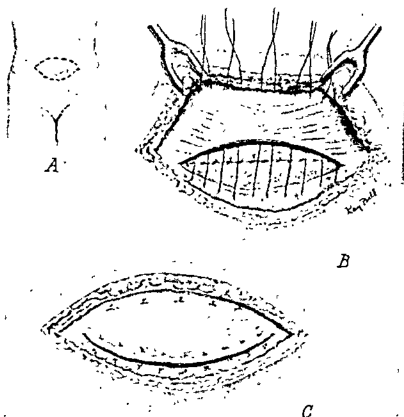


Fig. 391. MAYO OPERATION FOR REPAIR OF UMBILICAL HERNIA.

A, Transverse elliptical incision surrounding the hernial mass. The umbilicus should not be excised in children. *B*, The umbilicus and hernial sac excised and the peritoneum closed. Good exposure of the anterior rectus sheath. Interrupted mattress sutures are in place and ready to fix the lower leaf of rectus under the upper leaf. *C*, The upper rectus leaf imbricated anteriorly over the lower leaf. The homely term of "vest-over-pants" repair has been applied to this imbrication. (From Orr: Operations of General Surgery.)

The complications of hernia—inflammation, irreducibility and strangulation—are common in these lesions, so that surgical repair is a well advised procedure. Closure of the fascial defect after excision of the hernial sac is usually done by imbricating the upper and lower layer of the rectus sheath one over the other in an above-downward manner (Fig. 391). Imbrication from side to side may be carried out if it seems to fit better and causes less tension.

Abnormal Conditions Resulting from Partial or Complete Persistence of the Omphalo- (Vitello-) Intestinal Duct. In early fetal life the midgut has a wide communication with the yolk sac. As the abdominal walls approximate one another, the vitello-intestinal duct becomes narrower and lies within the umbilical cord. Under normal conditions the intestine finally is set free from all connection with the yolk sac and retires within the abdominal cavity, leaving no trace of the former connection with this structure. The vitello-intestinal duct may fail to undergo complete obliteration, and parts sometimes are found to persist up to adult life.

The incompletely obliterated duct may be found with its *proximal* or *intestinal end attached* to some portion of the ileum near the ileocecal valve, and its distal end free. This abnormality is known as *Meckel's diverticulum.* It springs from the antemesenteric border of the intestine and resembles in structure the intestine with which it is connected. The distal extremity terminates in a cul-de-sac in the manner of a glove finger. It varies in length, but 5 to 8 cm. may be regarded as the average. The diverticulum may be so small as to appear as a mere budlike process from the intestinal wall.

Meckel's diverticulum is a source of danger in the abdomen because it may become acutely inflamed as in appendicitis (Fig. 392). Sometimes it contains patches of gastric mucosa, *heterotopic gastric mucosa*, which may cause ulceration, pain and intestinal bleeding. A

borum. At the lateral margin of the erector spinae muscle the middle and posterior layers fuse to enclose this powerful muscle mass in a dense aponeurotic compartment. In its upper portion the middle layer is strengthened by the *posterior lumbocostal ligament*, which connects the transverse processes of the first and second lumbar vertebrae to the outer margin of the lowest rib. The medial attachment of the upper portion of the ligament to the transverse process of the first and second lumbar vertebrae is constant in all cases. The lateral termination of both portions of the ligament is attached to the twelfth rib, if it be present and of normal length, otherwise to the eleventh rib. The sharp edge of the ligament is an extremely important landmark for the inferior line of pleural reflection (p. 412) and should be avoided in operating.

The *anterior layer* of the lumbodorsal fascia is the least resistant, arises from the anterior surfaces of the lumbar transverse processes and their bases, and forms an anterior investment for the quadratus lumborum muscle. In its upper portion the layer is strengthened by the *lateral lumbocostal* (*external arcuate*) *ligament*, which is anterior and lateral to the posterior lumbocostal ligament, and serves as origin for some of the posterior fibers of the diaphragm. The ligament serves to protect the pleura in surgical exposure of the kidney and sometimes may be a considerable obstruction, particularly if the kidney lies high in the lumbar fossa. The anterior layer meets the fusion aponeurosis of the posterior and middle fascial layers at the lateral margin of the quadratus lumborum muscle, whence the broad lumbar aponeurosis runs laterally to merge into the fleshy band of the transversus abdominis muscle (Fig. 394). Through this broad aponeurosis lateral to the quadratus lumborum muscle, access is gained to the retrorenal spaces.

Posterior Abdominal Musculature. Superficial, middle and deep muscle groups may be considered in the musculature of the region.

The superficial musculature consists of the latissimus dorsi posteriorly and the external oblique laterally. Within the region, the *latissimus dorsi muscle* arises from the posterior third of the outer ridge of the iliac crest, from the lumbar and sacral spinous processes, and from the dorsal leaf of the lumbodorsal fascia (Fig. 393). Its fibers converge superiorly and laterally to attach by a flat tendon into the intertubercular (bicipital) groove of the humerus. In kidney incisions it may be cut or retracted posteriorly without serious damage to vessels or nerves deep to it. The anterior border of the latissimus dorsi, as it crosses the external oblique, may be separated below from the posterior margin of that muscle by a small triangular interval, the *inferior lumbar triangle* (of Petit). The base of the triangle is a portion of the iliac crest, and the floor is the internal oblique muscle.

The *superior* or *surgical lumbar triangle* lies under cover of the latissimus dorsi muscle and above and mesial to the lumbar triangle of Petit. Above, it is bounded by the twelfth rib; mesially, by the depression along the lateral margin of the sacrospinalis muscle; and below, by the superior border of the internal oblique near its origin from the lumbodorsal fascia. The floor of the space is the transversus abdominis aponeurosis, made up of the union of the three leaves of the lumbodorsal fascia. The triangle affords ready access to the retroperitoneal structures, and all kidney incisions, whatever their outside configuration, pass through it.

The fibers of the *external oblique muscle* which arise from the ninth, tenth and eleventh ribs descend obliquely downward and forward, and form a free posterior margin for that muscle within the region. In the kidney approach the posterior fibers may be drawn ventrally, save where the external oblique reaches far back. If the muscle must be sacrificed in the incision, it should be cut parallel to the lower ribs to avoid cutting nerves.

In the middle muscle group are the sacrospinalis, internal oblique and serratus posterior inferior muscles. The *sacrospinalis* (*erector spinae*) *muscle* occupies the aponeurotic compartment formed by the dorsal and middle layers of the lumbodorsal fascia (Fig. 394). It lies in the groove along the spinous processes from the sacrum to the neck, and is about a palm-breadth wide. In kidney incisions only the lateral bundles of the sacrospinalis muscle require consideration. When they must be cut, which rarely is the case, the incision should be made transverse to the fibers, 3 or 4 cm. below and parallel to the twelfth rib to avoid the larger vessels, the lateral and ventral branches of the last thoracic and first lumbar nerves, and the dorsal branches of the tenth and eleventh thoracic nerves.

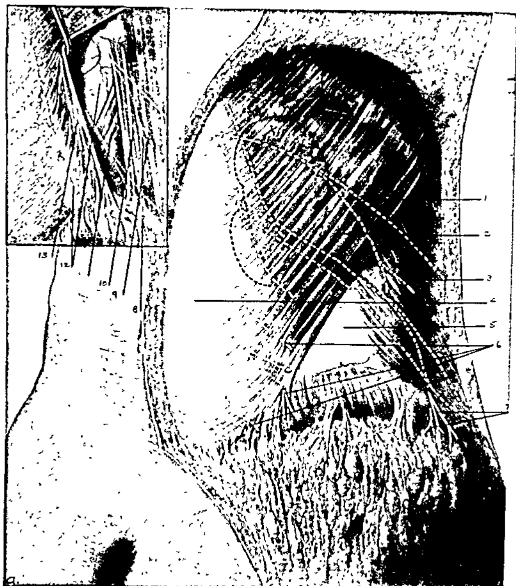


Fig. 393. SUPERFICIAL MUSCULAR LAYER OF THE POSTEROLATERAL ABDOMINAL WALL.

The main drawing shows the excessive fatty tissue of the loin, and an unusually wide lumbar trigone (of Petit); the inset shows a narrow lumbar trigone, with the internal oblique muscle cleared of fatty tissue; the outline of the kidney is shown in projection. 1, Ramus cutaneus posterior n. thoracalis XII; 2, M. latissimus dorsi; 3, M. obliquus externus; 4, fascia lumbodorsalis; 5, trigonum lumbale (Petit's triangle); 6, Nn. clunium superiores (rami cutanei dorsales a. rami posterioribus n. lumbalium I, II, III); 7, ramus cutaneus lateralis n. iliohypogastrici; 8, ramus cutaneus lateralis n. iliohypogastrici; 9, ramus cutaneus posterior n. thoracalis XII; 10, M. obliquus externus; 11, M. obliquus internus; 12, fascia lumbodorsalis; 13, M. latissimus dorsi. (After Kelly, Burnam.)

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Mm levatores costarum
M. serratus posterior inferior
Mm. intercostales externi
M. intertransversalis lateralis
Ligamentum lumbocostale posterior
M. quadratus lumborum
M. sacrospinalis
Lamina posterior fasciae lumbodorsalis
M. latissimus dorsi
M. obliquus internus
Fascia transversalis
M. transversus abdominis
Anterior layer of lumbodorsal fascia
Middle layer of lumbodorsal fascia
Aponeurosis m. transversi abdominis
Fascia lumbodorsalis
M. obliquus internus
M. obliquus externus

Fig. 394. TRANSVERSE SECTION THROUGH THE MUSCLES OF THE POSTEROLATERAL ABDOMINAL WALL.

Attention is called to the 3 layers of lumbodorsal fascia which fuse at the lateral margin of the quadratus lumborum muscle to form the aponeurosis of the transversus abdominis muscle. (After Kelly, Burnam.)

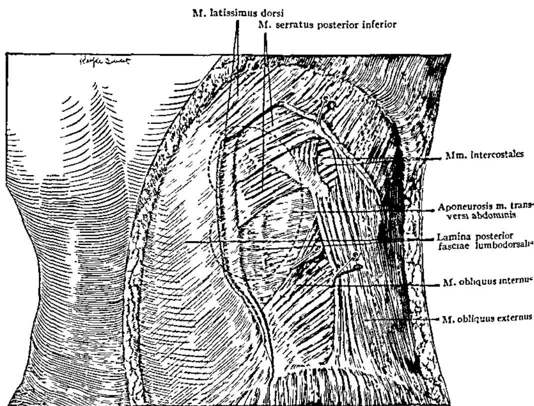


Fig. 395. DEEPER STRUCTURES OF THE POSTEROLATERAL ABDOMINAL WALL.

Part of the latissimus dorsi muscle has been removed to show the aponeurosis of the transversus abdominis, which all posterolateral kidney incisions must traverse. (After Kelly, Burnam.)

The *internal oblique muscle,* which arises from the iliac crest and inferior portion of the lumbodorsal fascia, sends fibers upward and forward which are encountered in operations in this region (Fig. 395). Its superior margin is the lateral boundary of the superior lumbar triangle. Any incision in the superior lumbar triangle which is enlarged anterolaterally will cut the muscle. The incision should parallel the lower rib to avoid cutting vessels and nerves.

The *serratus posterior inferior* is a thin, flat, quadrangular muscle which lies in the upper confines of the region, covered by the latissimus dorsi muscle and partly by the trapezius muscle. It arises from the dorsal layer of the lumbodorsal fascia and runs horizontally laterally to insert by digitations on the lowest four ribs. Its lowermost fibers are the upper boundary of the superior lumbar triangle. The lowermost bundle of the muscle lies superficial to the posterior lumbocostal ligament in almost the same relative position. As the pleura is on a level with the lumbocostal ligament (p. 412) or only a little above it, incisions should avoid injuring the muscle or the ligament deep to it. If it is necessary for the sake of good exposure to remove the lateral portion of the twelfth rib, the rib periosteum should be preserved carefully to avoid injury to the pleura.

The DEEP OR ANTERIOR MUSCLE GROUP includes the quadratus lumborum, the psoas major and the origin of the transversus abdominis. The *quadratus lumborum muscle* arises below from the iliac crest and from the iliolumbar ligament, which runs between the crest and the fifth lumbar transverse process (Fig. 394). It narrows as it passes upward to an insertion into the twelfth rib. The quadratus lumborum is contained within the fibrous compartment formed by the middle and anterior lamellae of the lumbodorsal fascia, and is separated from the transversalis fascia by the anterior lamella. In the upper portion it is strengthened anteriorly by the lateral lumbocostal ligament. The kidney, in normal position, extends from 1 to 3 cm. lateral to the lateral margin of the quadratus lumborum. Since this muscle can be drawn medialward, it is necessary only in an extraordinary case to sacrifice its lateral bundles.

The *psoas major muscle* occupies the gutter between the bodies and transverse processes of the lumbar vertebrae. It arises from the twelfth thoracic vertebra and all the lumbar vertebrae, and passes downward and laterally along the margin of the pelvic brim. As it passes beneath the inguinal ligament, it enters the thigh and inserts into the lesser trochanter of the femur. It forms a buffer between the kidney and the vertebral column. Because of its depth and medial position, the psoas does not come directly into consideration in renal operations. This muscle is enclosed in a stout membranous sheath. Pus tracking downward from tuberculous spondylitis of the thoracic vertebrae enters this muscular compartment and is directed into the thigh.

The part of the *transversus abdominis muscle* which figures in this region arises from the fusion aponeurosis of the three leaves of the lumbodorsal fascia (Fig. 394). This broad aponeurosis, in the lateral part of the region, assumes fleshy characteristics as it extends over the anterolateral abdominal wall toward the linea alba. The upper part of the transversus aponeurosis is strengthened considerably by the posterior lumbocostal ligament. The peritoneum is applied against the transversus abdominis muscle, from which it is separated by the transversalis fascia and the extraperitoneal fat.

VESSELS AND NERVES. The vessels of this area are the lowest or twelfth intercostal arteries and veins and the lumbar arteries and veins. The main trunks lie at a higher level than the terminal trunks which supply the region. The superior lumbar triangle is a relatively avascular space, the *twelfth intercostal artery* lying well in the upper part of the region. This artery has a larger area of distribution than have the other intercostals or the lumbar vessels. The ventral branch runs anterior to the quadratus lumborum muscle, while the dorsal branch runs behind it and the sacrospinalis muscle and supplies both of them. The main ventral branch passes laterally and downward to the broad abdominal muscles. It frequently is cut in superior lumbar trigone incisions.

The superior lumbar trigone lies between the twelfth intercostal and first lumbar nerves. The *twelfth intercostal nerve* runs along the upper margin of the trigone, and the *first lumbar nerve* along its medial and lower border. The ventral division of the first lumbar nerve has a larger iliohypogastric and a smaller ilioinguinal branch. These emerge between the psoas major and quadratus lumborum muscles and pass downward and laterally at a variable

M. levator costae brevis

Ligamentum lumbocostalis posterior

M. intertransversalis lateralis

Fascia lumbodorsalis (middle layer)

Fig. 396. RELATIONS OF THE KIDNEY WITH THE DEEP STRUCTURES OF THE POSTEROLATERAL ABDOMINAL WALL.

The posterior lumbocostal ligament and its relations to the inferior pleural reflection are emphasized.

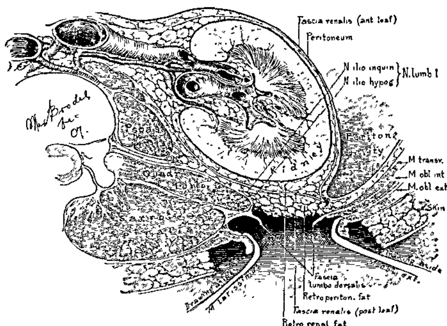


Fig. 397. CROSS SECTION THROUGH THE KIDNEY AND THE SUPERIOR LUMBAR TRIGONE TO SHOW THE STRUCTURES ENCOUNTERED IN THE LUMBAR APPROACH TO THE KIDNEY.

The perirenal fasciae and areas of fat about the kidney are emphasized. (After Kelly, Burnam.)

distance from the iliac crest. The higher-placed of the two, the *iliohypogastric nerve*, pierces the transversus abdominis aponeurosis and runs forward for a short distance between it and the internal oblique muscle (Fig. 350). The lower or *ilio-inguinal nerve* continues along the inner surface of the transversus aponeurosis until it perforates the transversus abdominis muscle near the anterior part of the iliac crest. It then pierces the internal oblique muscle and enters the inguinal canal (Fig. 345).

Surgical Considerations

LUMBAR APPROACH TO THE KIDNEY. No single incision admits of kidney exposure appropriate for all surgical procedures on that organ. The incision must be sufficiently large to admit free manipulation of the kidney with the hands, but must sacrifice a minimum of nerves, muscles and vessels. The severing of nerves is often followed by long-standing paresthesias. Individual variations in the distance between the twelfth rib and the iliac crest are many, and the deep and occasionally high location of the kidney often makes the operation more difficult. The incision must not injure the pleura (Fig. 396).

The nature of the operation determines to some extent the length and direction of the incision, the exposure for simple fixation of the kidney or for drainage of a perinephritic abscess varying greatly from that which permits careful handling of a large infected kidney. Resection of the twelfth rib may be required. In all lumbar kidney procedures the patient is placed with the sound side upon a lumbar

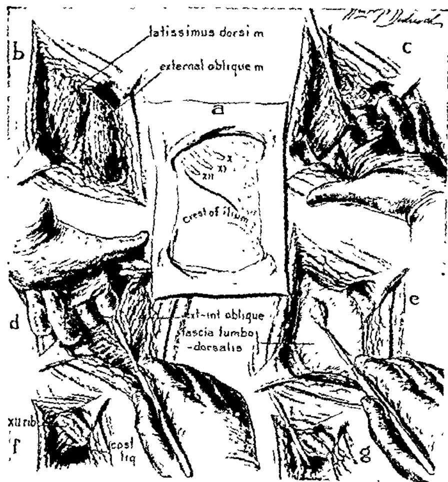


Fig. 398. EXTRAPERITONEAL LUMBAR NEPHRECTOMY.

a, Skin incision in flank. *b*, Latissimus dorsi and external oblique muscles exposed; also Petit's triangle (Fig. 393). *c*, Latissimus dorsi muscle divided. *d*, External and internal oblique muscles divided. *e*, Lumbodorsal fascia incised to expose the retroperitoneal fat. *f* and *g*, Costovertebral ligament exposed and divided. (From Lowsley and Kirwin: Clinical Urology. Baltimore, Williams & Wilkins Company.)

M. levator costae brevis

Ligamentum lumbocostalis posterior

M. intertransversalis lateralis

Fascia lumbodorsalis (middle layer)

Fig. 396. RELATIONS OF THE KIDNEY WITH THE DEEP STRUCTURES OF THE POSTEROLATERAL ABDOMINAL WALL.

The posterior lumbocostal ligament and its relations to the inferior pleural reflection are emphasized.

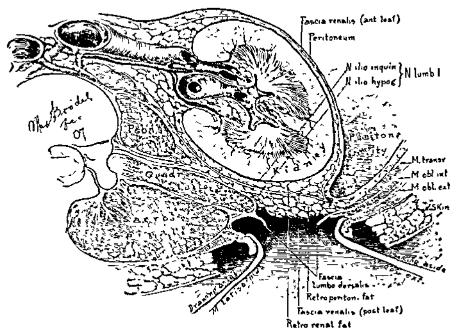


Fig. 397. CROSS SECTION THROUGH THE KIDNEY AND THE SUPERIOR LUMBAR TRIGONE TO SHOW THE STRUCTURES ENCOUNTERED IN THE LUMBAR APPROACH TO THE KIDNEY.

The perirenal fasciae and areas of fat about the kidney are emphasized. (After Kelly, Burnam.)

Abdominal Cavity and Contents

Intraperitoneal Viscera

The intraperitoneal viscera include the subdivisions of the gastrointestinal tube and the glands associated with them, namely, the liver, spleen and pancreas.

In the primitive stages the tube and adnexal glands are enveloped by peritoneum. Therefore, although rotation and posterior peritoneal fixation carry certain of the intestinal segments and the glands from their primordial intraperitoneal sagittal position to positions which are secondarily retroperitoneal, all the elements of the tube must be considered developmentally as intraperitoneal structures.

Topographically, these structures may be classified with reference to the transverse colon and mesocolon, which form a definite horizontal barrier across the abdomen. Above this barrier are the supramesocolic viscera—the stomach, spleen, liver, and bile passages, with portions of the duodenum and pancreas. Below the barrier are the inframesocolic viscera, which include a part of the duodenum, the subdivisions of the large bowel, and the jejunum and ileum.

At first the alimentary canal traverses the future abdominal (coelomic) cavity as a straight tube suspended posteriorly by an uninterrupted dorsal mesentery, and anteriorly by a ventral mesentery in the cranial (superior) portion of its extent (Fig. 400, *a*). Growing disproportionately, the tube lengthens more rapidly than does the embryonic body; concurrently, differentiation of the tube takes place to produce the ultimate segments, namely, stomach and large intestines (Fig. 400, *b*) and consequent subdivisions of the supporting mesenteries (mesogastria; mesoduodenum; mesentery of the jejuno-ileum; ascending, transverse and descending portions of the mesocolon). Early in development, the primitive stomach appears as a fusiform swelling (Fig. 400, *a*). With further enlargement of the stomach, the curvatures (greater and lesser) become evident; the duodenum becomes distinguishable through attainment of C-shaped form; the large intestine is demarcated from the small by the presence of the cecal enlargement (Fig. 400, *b*). The small intestines press anteriorly as a loop; upon retraction, the umbilical loop undergoes counterclockwise rotation in such a way as to carry the cecum and the future ascending colon across the abdomen under the liver. In the same process the descending portion approaches adult vertical position on the left wall of the cavity, and the coils of small intestine (jejuno-ileum) move caudalward and to the left (Fig. 400, *c*). In this change the gastroduodenal segment shares, undergoing rotation through 90 degrees on its longitudinal axis. The lesser curvature, originally ventral margin, now faces to the right; the greater curvature, primordially dorsal margin, to the left (toward the opposite side).

Between the layers of the dorsal mesentery of the stomach the pancreas and spleen have developed (Fig. 400, *d*). With rotation of the stomach a lesser portion of the peritoneal cavity is "trapped," to become the omental bursa (arrow in Fig. 400, *d*). The pouch is increased through redundant downward growth of the dorsal mesogastrium. In this way the mesogastrium (future greater omentum) comes to overlie the transverse colon (Fig. 400, *e*).

Up to this time the mesenterial supports retain virtually midline attachment and primitive mobility; the root of attachment is short in comparison with the length of the small and large intestine. In the succeeding, or final, stage of development, segments of the tube become fixed through permanent fusion of certain mesenterial supports with apposed areas of the parietal peritoneum (Fig. 400, *d*). The affixed mesenterial layers thus constitute a secondary parietal layer. Fusion may partially obliterate

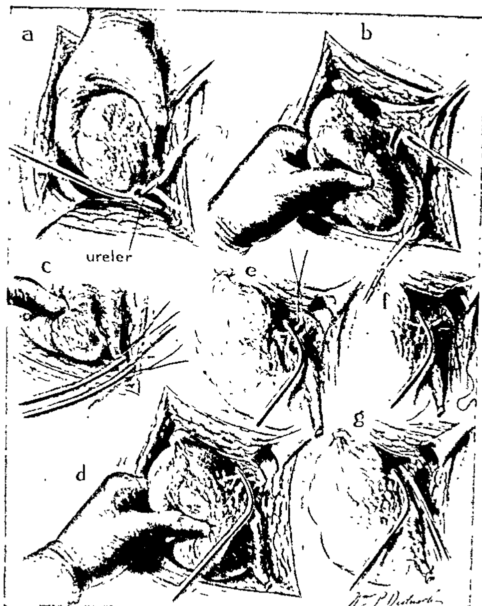


Fig. 399. EXTRAPERITONEAL LUMBAR NEPHRECTOMY (CONTINUED).

a, The kidney has been developed and brought up into the wound by incising the perirenal fascia (Gerota's capsule, Fig. 396) and by carefully pushing back adherent perirenal fat and adhesions by sharp and blunt dissection. The ureter is exposed and a tape placed around it. *b*, Perirenal fat is separated from the vascular pedicle. *c*, The ureter is clamped, divided and ligated. Ligation of the renal pedicle should be done carefully, and various methods are used to avoid serious hemorrhage. The following steps have been suggested to make sure that the pedicle is securely tied: *d*, a first clamp is applied that crushes the vascular pedicle as far medially as possible. *e*, The first clamp is removed, a second, more distal clamp is applied, and a stout ligature is placed around the pedicle vessels at the site of the crushing by the first clamp. *f*, Two ligatures are tied around the renal pedicle some distance apart, and a transfixing suture is placed close to the proximal ligature. *g*, The transfixing suture has been tied and the pedicle divided distal to the 2 proximal ligatures. (From Lowsley and Kirwin: Clinical Urology. Baltimore, Williams & Wilkins Company.)

support which rounds out the involved region prominently, increasing the costo-iliac space to the maximum.

In most cases an extraperitoneal lumbar approach to the kidney or perirenal area is selected (Figs. 397 to 399). Recently, and for special circumstances such as large tumors, a thoracoabdominal approach* has been used and excellent exposure obtained.

* O'Conor and Head: Transthoracic Nephrectomy (Right) for Tuberculosis of the Kidney. Surg., Gynec. & Obst., 89: 599-604, 1949.

dition the continuities may be traced by sagittal and transverse sections through the trunk. When the peritoneum of the general cavity is traced downward (sagittal section, Fig. 400, *h*), it is found to be continued from the inferior surface of the diaphragm to the liver, where it is reflected on the superior surface and, then, inferior surface, rounding the *inferior border. It is continued backward* (posteriorly) as far as the attachment of the lesser omentum, where it is reflected as the anterior layer of the latter, to the lesser curvature of the stomach and to the duodenum. Investing the anterosuperior surface of the stomach as a serous coat, it next quits the organ along the greater curvature, to descend as the anterior layer of the greater omentum. Nearing the pelvis, the membrane returns upon itself, to pass upward to the transverse colon. After covering the colon behind, it continues ascent to the posterior abdominal wall, which it reaches at the level of the pancreas.

Within the lesser sac (omental bursa) the peritoneum clothes the inferior surface of the liver; therefrom it descends to the lesser curvature of the stomach as the posterior layer of the lesser omentum (Fig. 400, *h*). Covering the stomach on its postero-inferior surface, it descends from the greater curvature to form the posterior lamella of the greater omentum. Having attained the distal extremity of the omentum, it turns upward, initially to cover the transverse colon, then to reach the dorsal body wall as the parietal peritoneum. On the left side the course to the body is shorter and is *interrupted by the spleen; from the greater* curvature of the stomach to the spleen it forms the inner layer of the gastrolienal ligament; from the spleen to the diaphragm it is the phrenicolienal ligament. On the posterior wall of the bursa the peritoneum covers the diaphragm, the artery and inferior vena cava, the *left kidney and adrenal gland.*

The peritoneum, when traced transversely around the abdominal cavity, presents a more complex set of relations at gastric level than at colic level. Cranial to the level of the transverse colon, the peritoneum covers the pancreas. At the level of the left kidney the peritoneum is reflected to the spleen as the deep layer of the phrenicolienal (or lienorenal) ligament, and therefrom to the greater curvature of the stomach as one layer of the gastrolienal ligament. For the posterior surface of the stomach it forms a serous investment; prolonged from the lesser curvature, it forms a deep layer of lesser omentum. At the free edge of the lesser omentum, on the anterior wall of the omental bursa, the peritoneum becomes continuous with the superficial layer of the omentum, as the two lamellae invest the hepatic artery, common bile duct and portal vein.

Just above the level of the iliac crests, the course of the peritoneum is simple. From the anterior abdominal wall the peritoneum passes around on each side to the posterior parietes; *en route* to the midline it is carried over (superficial to) the colon, ascending colon on the right

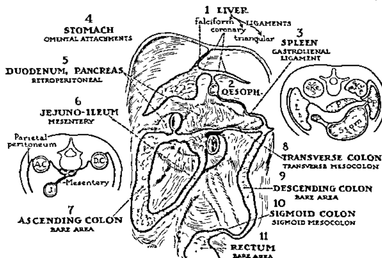


Fig. 401. MESENTERIAL REFLECTIONS AND AREAS OF SEROUS INVESTMENT IN THE ADULT.
Shown schematically by cutting the mesenterial supports along their lines of continuity with the parietal peritoneum, and by transecting the body at gastric and colic levels. See text for description of the numbered areas.

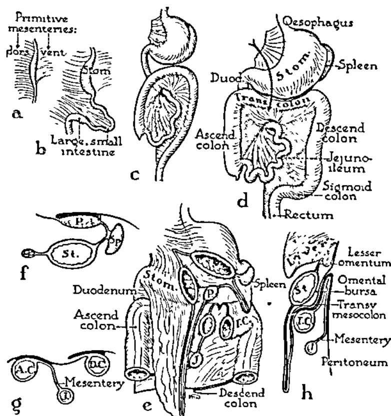


Fig. 400. DEVELOPMENT OF THE GASTROINTESTINAL TRACT AND THE SEROUS SUPPORTS.

a, Primitive mesenteries. *b*, Early differentiation of the tract. *c*, Rotation of the stomach and intestines. *d*, Fixation (stippled areas) of portions of the mesentery and mesocolon. *e*, Interrelationship of the bilaminar serous supports prior to fusion with each other in the omental region. *f* and *g*, Fusions at gastric and colic levels, respectively, as shown by transverse sections *h*, Reduction in extent, through fusions, of the omental bursa, greater omentum and mesentery of the small intestine.

a mesentery, merely to reduce its length and alter the position of its root; or obliteration may be complete, to place the particular segment of the tube into retroperitoneal position (being then partially invested by the serous lining of the abdominal cavity). In this process the following secondary attachments are produced: the dorsal mesogastrium is reduced in length, and the pancreas assumes retroperitoneal position (Fig. 400, *f*). The remainder is thereby divided into two portions, namely, gastrolienal and phrenicolienal ligaments, by the interposition of the spleen (Fig. 400, *d*, *e*, *f*). The mesentery of the jejuno-ileum is similarly reduced, and the ascending mesocolon obliterated, by a similar process (Fig. 400, *g*, *h*). In comparable manner the space of the omental bursa (earlier enlarged through downgrowth of the ventral mesogastrium) becomes reduced in its caudal portion through fusion of the facing layers of serous membrane (Fig. 400, *e*, *h*). The apposed (anterior) lamella of the primitive transverse mesocolon fuses to the posterior layer of the mesogastrium (Fig. 400, *h*); the consequent conversion of four serous layers into two means that the transverse mesocolon of the adult is derived from embryologically distinct mesenterial supports. This secondary attachment is transverse; occurring at the point where the dorsal mesogastrium contains the pancreas, the latter viscus becomes retroperitoneal by such secondary fixation (Fig. 400, *f*). Fusion is carried toward the right; the mesoduodenum is thus obliterated, converting the duodenum, likewise, to retroperitoneal status. Distally (inferiorly) the sigmoid mesocolon is reduced in length, the mesorectum obliterated (Fig. 400, *d*).

In this way no portion of the digestive tube retains its full mesenterial support. In alternating succession, segments are either held by shortened mesenteries or affixed, in subserous position, to the dorsal body wall. Still mesenterial are the following: stomach, jejuno-ileum, transverse colon and sigmoid colon; in retroperitoneal situation are the duodenum, ascending colon, descending colon and rectum.

In the resultant established, or adult, con-

and descending colon on the left, covering (i.e., partially investing) the front and sides of each and leaving the posterior surface bare (i.e., against retroperitoneal tissue). Continuing medialward, it covers the psoas muscles, the mesenteric vessels and their branches. From both sides the peritoneum is carried forward on the veins and arteries, forming the right and left layers of the mesentery. Reaching the small intestine, the peritoneum invests it completely, the two portions then becoming continuous.

As the parietal peritoneum (which lines the abdominal and pelvic cavities) is carried outward (ventralward) to cover the organs as a visceral layer, it is stretched out between parietes and viscus in a series of mesenterial supports for the stomach, the jejuno-ileum, the transverse colon and the sigmoid mesocolon (Fig. 401). Alternately, other segments of the digestive tube and the glandular outgrowths therefrom are fixed to the dorsal body against so-called bare areas; the serous layer passes over them, to give but partial investment, as they lie in retroperitoneal position. In this latter category are the liver, the duodenum with the pancreas, the ascending and descending portions of the colon, and the rectum. The lines and areas will now be traced in succession.

From the diaphragm and, at a lower level, from the posterior abdominal wall the peritoneum is carried downward and forward to be draped over the round ligament and the liver (Fig. 401 at 1). Over the former it forms the falciform ligament, and over the liver it is reflected as the right and left coronary ligaments and their narrower marginal portions, the right and left triangular ligaments. The bare area is an exposed, subserous field bounded by the four ligaments just named. From the middle of the left coronary ligament the peritoneal reflection descends to enclose the esophagus (Fig. 401 at 2). Therefrom, in its further descent, the peritoneal reflection is deflected to the left and constitutes the phrenicolienal (diaphragm) to the spleen, the latter viscus subdividing the primordial dorsal mesentery of the stomach (Fig. 401 at 3). The gastrolienal (gastrosplenic) ligament passes from the spleen to the stomach (as the second part of the original dorsal mesentery of the stomach, or dorsal mesogastrium). At its inferior (caudal) extremity the gastrolienal ligament meets the transverse mesocolon.

Returning to consideration of the proximal portion of the digestive tube, it must be pointed out that the stomach has no direct attachment to the diaphragm or to the abdominal wall (Fig. 401 at 4); superiorly, its lesser omentum is attached to the inferior surface of the liver; inferiorly, its greater omentum is interrupted by the transverse colon; on the body's left the spleen intervenes similarly. However, the succeeding segment, the duodenum or first part of the small intestine (Fig. 401 at 5), is directly related to the posterior parietes; with the adjacent pan-

Fig. 402. VARIATIONS IN POSITION OF PARTS OF THE DIGESTIVE TUBE AND OF THE GREATER OMENTUM.

Data from 125 consecutive specimens. Within each set (liver, stomach, transverse colon, and so on), the examples are arranged in the order of increasing distance from the xiphisternal articulation. A percentage placed near a figure indicates the approximate fraction of 125 cases which the illustration represents; a percentage between figures, encircled, indicates the approximate fraction of cases which fall between the adjacent figures. The illustrations of the liver (*A* to *E*) were selected to show the costal relations of the left lobe, since the right lobe was concealed in 38 per cent of the cases. In 34 of 120 specimens the caecum was not in view, being covered by the coils of small intestine or by the omentum; in the 86 cases in which it was showing, its inferior margin was situated superior to the anterior superior iliac spine in 42, opposite the spine in 26, inferior to it in 18.

Liver. In 94 per cent of the 125 sets of organs the left lobe of the liver projected below the xiphisternal articulation to an extreme descent of 18.5 cm. (*E*). In only 6 per cent of the cases was it entirely concealed in anterior view, reaching an extreme height of 2 cm superior to the notch (*A*).

Stomach. In 16 per cent of the cases the stomach was entirely concealed by the liver and the transverse colon (*F*). Invariably covered in at least a portion of its anterior aspect by the liver—upon whose position its own seemed largely to depend—its greater curvature in 42 per cent of the cases extended below the xiphisternal articulation for a distance of 5 cm. (*G*) to 13.5 cm. (*H* and *I*), and for a distance of 14 to 25 cm. (*J*) in 42 per cent. The stomach variously occupied the infrasternal notch (*G*), the subcostal space near the left lobe (*H*), the notch between the lobes (*I*), and a wider area inferior to the anterior margin (*J*).

Transverse colon. In 13 per cent of the cases (not illustrated) the transverse colon was not in view inferior to the liver or stomach; in 58 per cent its lower margin extended for a distance of 8 cm. (*K*) to 21 cm. (*L*) below the xiphisternal articulation, in 29 per cent for 21.5 to 33 cm. (*M*).

Greater omentum. The greater omentum was not in view in 19 per cent of the cases (*N*), and appeared as a mere fringe in an additional 2 per cent (*O*), in 8 per cent it extended 14 to 19.5 cm. (*P*) below the xiphisternal articulation; in the remaining 71 per cent from 20 to 36 cm. (*Q* and *R*). (From Anson, Lyman and Lander: Anat. Rec., 67: 17–21, 1936.)

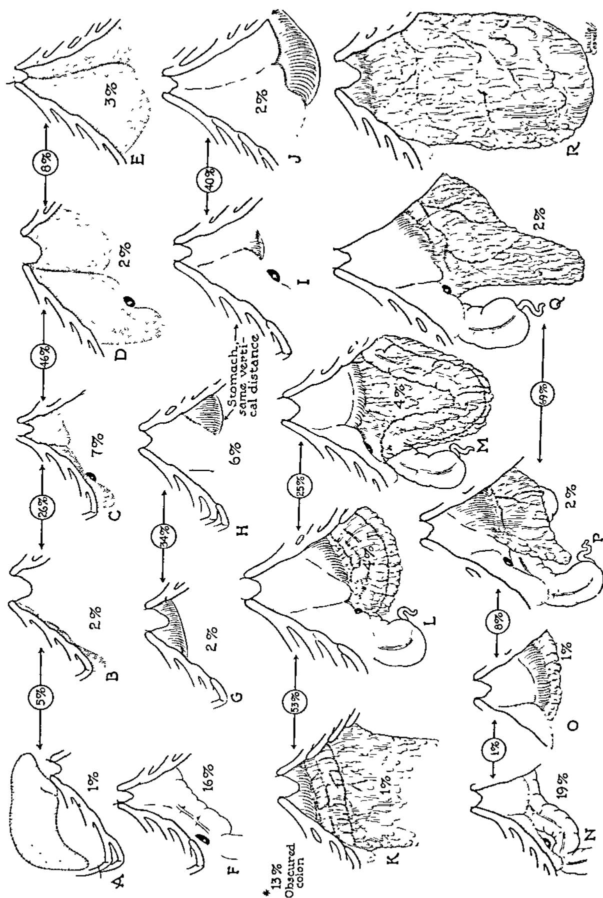

A
1%
5%
B
2%
26%
C
7%
46%
D
2%
8%
E
3%
F
16%
G
2%
34%
H
6%
Stomach, same vertical distance
I
40%
J
2%
* 13% Obscured colon
K
1%
53%
L
4%
25%
M
4%
Q
2%
R
N
19%
1%
O
1%
8%
P
2%
69%

Fig. 402

Fig. 403. SUPRAMESOCOLIC VISCERA AND THEIR RELATIONS WITH THE THORACIC CONTENTS.

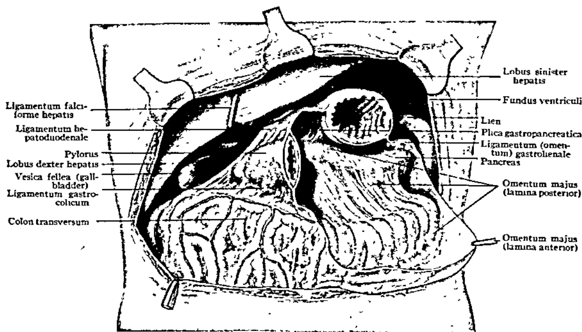


Fig. 404. SECTION OF THE STOMACH REMOVED TO SHOW THE GASTRIC ORIFICES AND THE RELATIONS OF THE VISCUS TO THE LESSER PERITONEAL CAVITY.

creas it is in retroperitoneal situation. The jejunum and the ileum, which constitute the succeeding, coiled portions of the small intestine, are supported by the mesentery (Fig. 401 at 6); its line of attachment (root, or radix) begins at the duodenojejunal junction, to the left side of the second lumbar vertebra; descending therefrom in oblique course toward the right, it terminates in front of the right sacroiliac articulation. Like the duodenum, part of the cecum and of the ascending colon have lost their mesenterial supports (through embryonic fusion with the parietal peritoneum); as a consequence, they are retroperitoneal (bare area at 7 in Fig. 401). The next, or transverse, segment of the colon, having retained a mesenterial support, is supported by the transverse mesocolon (Fig. 401 at 8). This mesentery begins at the right colic, or hepatic, flexure and ends at the left colic, or splenic, flexure of the colon. Its line of attachment marks the inferior (caudal) boundary of the main portion of the omental bursa; the other boundaries are the lines of attachment of the phrenicolienal ligament (Fig. 401 at 3); laterally, the inferior portions of the coronary ligaments (Fig. 401 at 1) and that of the right triangular ligament. Like the ascending colon, the descending part of the large intestine lacks a mesentery (Fig. 401 at 9). However, the succeeding, or sigmoid, portion of the colon has a mesenterial support, the sigmoid mesocolon (Fig. 401 at 10), whose S-shaped line of attachment crosses the iliac fossa in the greater pelvis, the pelvic brim, and attains presacral position in the lesser pelvis. The next segment of the large bowel, namely, the rectum, devoid of mesorectal attachment, lies against a bare area (Fig. 401 at 11) in front of the sacrum.

Although the abdominal portions of the digestive tube and the omenta may be said to occupy typical positions in relation to surface areas of the abdominal wall, departures from the anatomic "normal" are common, as would be expected from consideration of the mobility of their serous supports (Fig. 402).

SUPRAMESOCOLIC VISCERA

STOMACH

The stomach is a local expansion of the alimentary tube interposed between the termination of the esophagus and the beginning of the small intestine (Fig. 403). It is shaped like a cornucopia which, when filled with barium and viewed under the fluoroscope, appears as a reversed cone with its lower extremity curved mesially to the right. Its shape is modified by various factors, among which are functional activity, volume of contents, disease, and changes in the surrounding viscera. The stomach varies greatly in size, being enlarged enormously in postoperative atony or in pyloric obstruction, and so shrunken in esophageal cancer that it may be no larger than the transverse colon. In this event the arterial networks on its curvatures lie in close apposition.

Gastric Orifices. The *cardiac orifice* (*cardia*) is the point of junction of the esophagus and stomach and marks the level at which the curvatures begin. The *pylorus* is more mobile than the cardia and is more likely to vary in position. The junction of the stomach with the duodenum is marked externally by a circular narrowing, the duodenopyloric constriction, and internally by the pyloric valve. The pylorus occupies a plane antero-inferior to the cardia.

Subdivisions of the Stomach and Their Relations. The *fundus* is that expanded upper extremity of the stomach lying to the left of the cardia and surmounting the body like a dome (Figs. 403, 404). In the supine position it bulges markedly upward into the left cupola of the diaphragm until its superior limit extends behind the apex of the heart and the pericardium at the level of the fifth rib posteriorly. Distention of the fundus may produce cardiac discomfort mechanically by direct pressure. In the erect position the volume of the fundus is diminished, and its outline tends to become absorbed into the greater curvature. The *body* of the stomach lies between the fundus and the pylorus, and its general direction is oblique.

The *pyloric portion* of the stomach is the attenuated right extremity, limited externally by the *duodenopyloric constriction*, and internally by the pyloric orifice (Figs. 403 to 405). This portion, when distended, has a sacculated outline, divided into lesser sacculi by an intermediate sulcus. The larger sacculus, lying to the left, is the *pyloric vestibule*, and the much narrowed part to the right is the *pyloric antrum*. The tube-shaped *pyloric canal* is about 2.5 cm. long and communicates with the duodenum through the pylorus (Fig. 405).

Part of the anterior surface of the stomach comes forward into the epigastrium and lies

Cavum mediastinale anterius
Pulmo dexter
Pericardium
Pleura diaphragmatica
Ligamentum teres hepatis
Vesica fellea (gall-bladder)
Lobus dexter hepatis
Ligamentum hepatoduodenale
Foramen epiploicum (Winslowi)
Ligamentum hepatorenale
Pars descendens duodeni
Ren dexter
Omentum majus
Flexura coli dextra
Pulmo sinister
Pleura pericardiaca
Diaphragma
Lobus sinister hepatis
Lobus quadratus hepatis
Pars condensa omenti minoris
Pars flaccida omenti minoris
Ventriculus
Lien
Pars pyloris ventriculi
Ligamentum gastrocolicum

Fig. 403. *SUPRAMESOCOLIC VISCERA AND THEIR RELATIONS WITH THE THORACIC CONTENTS.*

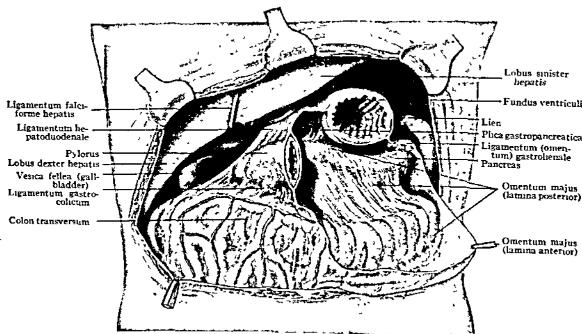


Fig. 404. SECTION OF THE STOMACH REMOVED TO SHOW THE GASTRIC ORIFICES AND THE RELATIONS OF THE VISCUS TO THE LESSER PERITONEAL CAVITY.

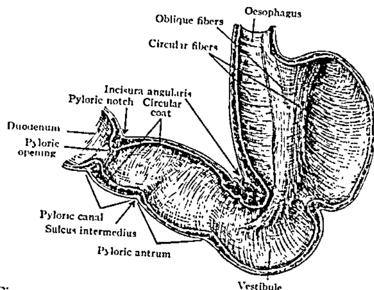


Fig. 405. MUSCULAR COATS AND DIVISIONS OF THE STOMACH. The anterior half of the stomach has been removed. (After Cunningham.)

behind the anterior abdominal wall. The lower boundary of the stomach, when the viscus is distended moderately, corresponds to a horizontal surface line connecting the tenth costal cartilages. By resection of a portion of the left costal margin, it is possible to gain wider access to the stomach without risk of opening the pleural cavity.

Posteriorly to the left, the stomach rests upon the spleen, which is hollowed to receive it. In the narrow interval between the spleen and pancreas, only the peritoneum of the lesser sac lies between the stomach and the anterior surface of the left kidney. The anterior surface of the body and tail of the pancreas is molded to the stomach. Because of these relations, adhesions of the posterior wall of the stomach to the peritoneum of the lesser sac over the pancreas, celiac axis, and aorta commonly occur after penetrating and perforated gastric ulcer, and are troublesome in operative procedures on the stomach.

CURVATURES AND THEIR RELATIONS. The convex *greater curvature*, on the left side of the stomach, begins at the cardia in the depth of the sharp angle between the esophagus and the fundus. It is directed posterosuperiorly over the fundus and then anteriorly from left to right with an inferior inclination. It assumes an upward bend as it approaches the pylorus (Fig. 403). Below the level of the fundus, the curvature is related to the arterial arch formed from the right and left gastro-epiploic arteries lying within the layers of the gastrocolic ligament.

The concave *lesser curvature* defines the right margin of the stomach and has vertical and horizontal segments which join at the angular incisure (Figs. 403, 405). It is continuous, without any line of demarcation into the right margin of the esophagus. The curvature affords attachment for the gastrohepatic or lesser omentum, and is related to the arterial circle contained therein, which consists of the right and left gastric (coronary) arteries (Fig. 467, *b*).

POSITION OF THE STOMACH. By far the greater part of the stomach lies in the left hypochondrium, and the remainder in the epigastrium, where it is supported, to a considerable degree, by the sloping transverse mesocolon upon which it rests (Figs. 403, 404). The organ is maintained in position mainly by its continuity with the abdominal esophagus, which is fixed solidly to the esophageal hiatus in the diaphragm. Below, it is held firmly in position by continuity with the duodenum, which is anchored securely over most of its extent to the posterior parietal peritoneum. The arteries from the celiac trunk and the various peritoneal ligaments and omenta contribute to the stability of its position. The small intestine pressing upward prevents any marked degree of inferior displacement.

The position of the stomach is subject to wide variation. In erect posture the posteroinferior surface of the stomach slides downward and forward on the sloping ledge of the transverse mesocolon which supports it. Fur-

ther change in position is rendered possible by the slight descent of the diaphragm and the elasticity and loose attachment of the peritoneum. At the same time the pylorus undergoes a considerable change in position, permitted by the two factors enumerated and by the normal mobility of the first portion of the duodenum. Because of the uniformity with which this downward displacement is observed in roentgenograms in erect posture, the presence of an immobile, high-placed pylorus suggests the possibility of its immobilization by adhesions to the gallbladder and neighboring structures.

STRUCTURE OF THE STOMACH. An investment of peritoneum gives the stomach a complete *serous* coat, save at the reflections of the omenta at the curvatures, and a small area at the left of the cardia which is in direct contact with the diaphragm. The *musculature* consists of three layers of involuntary muscle: an outer longitudinal, a middle circular and an inner oblique (Fig. 405). At the pylorus the circular middle layer thickens to form the pyloric sphincter. In infants excessive thickening of the circular layer at the pylorus from continued spasm or actual hypertrophy may give rise to *congenital pyloric stenosis* (Fig. 406). Operative relief of this condition contemplates longitudinal division of all the layers of the pylorus save the mucosa, which is allowed to bulge into the wound (Fredet-Ramstedt) (Fig. 412).

The *mucosa* is thick and highly vascular, and has such ready play over its submucosal base that in incisions into the stomach, as into the esophagus, it may easily be pushed ahead of the knife. In small puncture wounds the

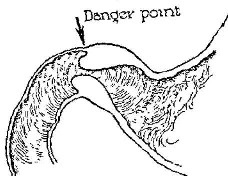


Fig. 406. LONGITUDINAL SECTION THROUGH AREA OF HYPERTROPHIC PYLORIC STENOSIS.

Note how increased muscle mass causes the pylorus to bulge into the duodenum. The "danger point" is the spot where a longitudinal incision carried too far distally may inadvertently open into the duodenum.

mucosa may plug the opening so effectively that there is no escape of gastric contents. The toughness of the loose *submucosa* explains its ability to hold gastric sutures.

ARTERIES AND VEINS OF THE STOMACH. The stomach receives a rich arterial supply from the celiac (axis) artery, which arises from the aorta just above the neck of the pancreas and at once trifurcates into the left gastric (coronary), splenic and hepatic arteries (Fig. 407). These trunks and their branches form two arterial arches related respectively to the greater and lesser curvatures. The arch of the lesser curvature consists of the right gastric branch of the hepatic artery running from right to left, and the left gastric (coronary) artery running from left to right. The arch of the greater curvature is contained within the layers of the great omentum, and is made up of the gastro-epiploic artery from the gastroduodenal and the left gastro-epiploic artery from the splenic artery. The relations of these arches to the stomach vary. When the stomach is empty, each arch is tortuous and is 1 to 2 cm. distant from the corresponding curvature. With distention of the stomach, both arches come into close contact with the wall, but are not stretched to any great degree.

The HEPATIC ARTERY runs to the right along the upper border of the pancreas, turns forward just below the epiploic foramen, and reaches the first part of the duodenum. Together with the common bile duct and portal vein, it turns upward and ascends to the liver in front of the epiploic foramen between the two layers of the lesser omentum (Fig. 424). In passing around the epiploic foramen, it gives off the *right gastric (pyloric) artery* and, at the upper border of the first part of the duodenum, the *gastroduodenal artery*, which descends behind the duodenum to its lower margin, where it divides into the *superior pancreatico-duodenal* and *right gastro-epiploic arteries* (Figs. 407, 467).

The LEFT GASTRIC (CORONARY) ARTERY runs upward to the left to the beginning of the lesser curvature at the cardia, and divides into two parallel branches which anastomose with the right gastric (pyloric) artery.

The SPLENIC ARTERY runs to the left under the peritoneal floor of the lesser peritoneal sac (omental bursa) along the upper margin of the body and tail of the pancreas, until it reaches the hilus of the spleen. The *short gastric* and

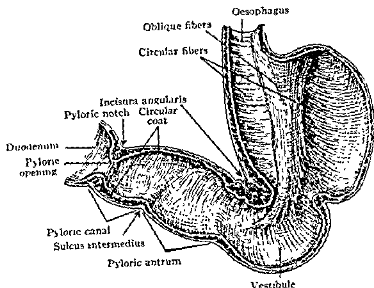


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areas of both surfaces of the stomach and run at a right angle to its long axis (Figs. 407, 467).

The GASTRIC VEINS correspond to the arteries and empty into the large splenic and superior mesenteric trunks of the portal vein or into the portal vein itself. The *left gastric (coronary) vein*, tributary to the portal system, anastomoses freely with the lower esophageal veins. The lower esophageal veins anastomose with the upper esophageal veins, which are tributary through the azygos veins with the caval venous system. This forms an important anastomosis between the portal and systemic venous systems. The veins at the inferior end of the esophagus become varicose in portal obstruction (p. 448), and their rupture, with resulting hematemesis, may be the first sign of the condition.

LYMPHATICS OF THE STOMACH. The abundant lymph vessels of the stomach originate in the mucosa and ramify in plexuses of the submucosa and muscularis. From there, channels lead to the lymph nodes, mainly along the greater and lesser curvatures (Fig. 408). Three main groups of such nodes are generally described, the first lying high up along the cardia and lesser curvature. These nodes, situated in front of and behind the cardiac orifice, are in continuity superiorly with glands along the lower esophagus, and inferiorly follow the lesser curvature and the course of the left gastric artery. The second group includes the hepatic and subpyloric glands. The latter are in continuity with the lymph nodes along the greater curvature of the stomach and drain its lower two thirds. Special attention is needed to remove the subpyloric glands by careful dissection. The third group of lymph nodes lies along the greater curvature of the stomach and close to the hilum of the spleen. These glands drain the lower half and the fundus of the stomach. It is for the pancreaticolienal group that splenectomy is considered with resection of the stomach in the presence of extensive involvement of these nodes. There is a close relation between these various perigastric lymph nodes and the rich network of posterior glands lying about the pancreas and retroperitoneal vessels.

In planning any resection of the stomach for carcinoma, the surgeon must be aware of the extensive lymph node distribution, and carefully remove all possible glands with the gastric segment. The subpyloric nodes and those of the lesser curvature are most often involved. If the location of the tumor suggests greater curvature involvement, nodes in the omentum often show metastases, so that removal of the entire greater omentum is commonly done. The spleen is frequently also removed with the block of tissue. Many resections nowadays are

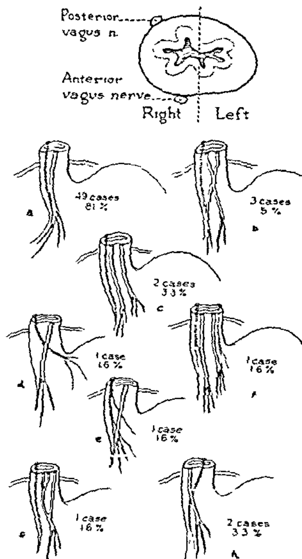


Fig. 409. DISTRIBUTION OF THE VAGUS NERVES ALONG THE LOWER PORTION OF THE ESOPHAGUS AND UPPER PART OF THE STOMACH IN 60 HUMAN DISSECTION SPECIMENS.

Note that in 81 per cent of the cases the distribution is as illustrated in *a*.

The cross section of the esophagus just below the diaphragm shows the most frequent positions of the posterior and anterior vagus nerves. Both lie on the right of the esophagus. (*From Dragstedt, Fournier, Woodward, Tovee and Harper: Surg., Gynec. & Obst., 85: 461-6, 1947.*)

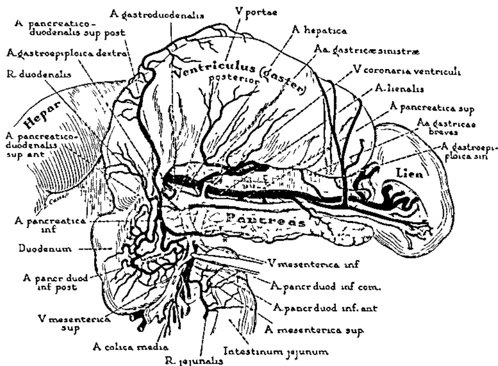


Fig. 407. THE ARTERIES OF SUPPLY OF THE STOMACH, PANCREAS, DUODENUM AND SPLEEN.

The stomach is elevated to show the retrogastric structures. (Hambley, Sielert and Anson, unpublished study.)

left gastro-epiploic arteries arise from the splenic artery near its termination and run forward in the gastrosplenic omentum to the greater curvature of the stomach. The short gastric arteries are distributed to the fundus, and the left gastro-epiploic artery anastomoses with the right gastro-epiploic artery.

In brief, the celiac artery supplies the stomach directly by the left gastric (coronary) artery and indirectly by the right gastric and right gastro-epiploic arteries from the hepatic artery, and the short gastric and left gastro-epiploic arteries from the splenic artery. The branches given off by these vessels supply adjoining

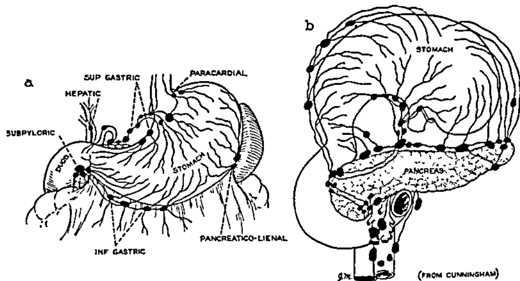
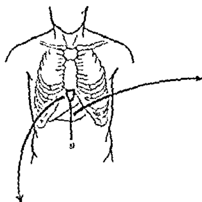
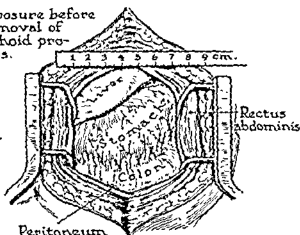
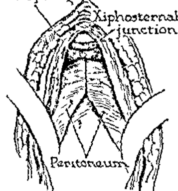


Fig. 408. LYMPH DRAINAGE OF THE STOMACH IN RELATION TO GASTRECTOMY FOR CANCER.

a, Perigastric groups of nodes are abundant. In cancer the subpyloric glands must be carefully dissected; to remove those along the greater curvature, the entire greater omentum should be excised. Including the spleen in the dissection cuts out the pancreaticolienal glands. *b*, The extensive lymph node field presents posterior to the stomach and with many connecting channels. Portions of the pancreas and transverse colon may require excision. Toward possible cure, resections of the stomach for carcinoma may include all or part of several surrounding organs and should be nearly total, or total gastrectomies. (From Lahey and Marshall: Ann. Surg., 132:540–65, 1950.)







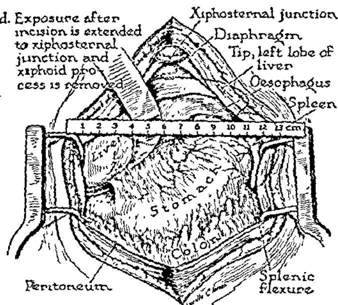


Fig. 410 ENLARGEMENT OF THE OPERATIVE FIELD BY REMOVAL OF THE XIPHOID PROCESS AND UPWARD EXTENSION OF THE MIDLINE INCISION.

Full advantage of removal of the xiphoid lies in the fact that it is now possible to increase further the size of the wound by incising the diaphragm and its peritoneal lining upward toward the dome of this muscle for a distance of no less than 4 to 5 cm. A marked increase in exposure is thus obtained. (From Saint and Braslow: Surgery, 33: 361-6, 1953)

ment of an artificial stoma in the stomach wall for administering nourishment, and is resorted to in fibrous or malignant stricture of the esophagus and occasionally for inoperable carcinoma of the stomach. The main feature of all techniques described for this operation is the desire to make a long and somewhat valve-acting opening leading from the skin into the stomach cavity, which will admit liquid food and prevent the escape of gastric contents. The simplest methods of doing a gastrostomy are those of Stamm or Witzel. The operation may be performed through a left upper quadrant transverse incision or a paramedian vertical incision, and the gastrostomy tube is usually brought out through a lateral stab wound, the stomach being sutured snugly to the peritoneum at that point.

Pyloroplasty. Pyloroplasty is an operation designed to enlarge the constricted lumen of the pylorus in congenital hypertrophic stenosis (Figs. 412, 414) or as a result of inflammation from a long-standing duodenal ulcer. For the latter condition it is seldom used independ-

practically total gastrectomies, and total gastrectomy is frequently carried out.*

VAGUS NERVES TO THE STOMACH. The introduction by Dragstedt and his associates of complete division of the vagus nerve supply to the stomach as a method of treatment for duodenal ulcer has focused the attention of the surgeon and the anatomist alike on these structures. A complete division of these nerves brings about a decrease in the volume and acidity of the continuous night secretion, which is particularly high in duodenal ulcer patients. Complete vagotomy is not an easy procedure to accomplish. If a single small vagus fiber is left uncut, the desired profound decrease in gastric secretion may not occur.

Since most vagotomies are now done through an abdominal approach, it is essential that the surgeon know about the frequent variations in these nerves below the diaphragm (Fig. 409).

Surgical Considerations

ROENTGENOLOGIC EXAMINATION OF THE STOMACH. In the erect position the normal stomach appears horn-shaped or J-shaped in roentgenograms taken after an opaque meal (barium). The longer limb of the J is vertical and is to the left of the median line. The barium is well supported in the vertical segment by the muscle of the healthy stomach wall, and fills the shorter limb, which corresponds to the pyloric portion. The usual roentgenogram of a normal stomach shows a small, caplike shadow immediately above the barium in the pyloric antrum, separated from it by a clear area. The cap is the barium contained in the first part of the duodenum, and the clear area corresponds to the pyloric canal, which is closed by the contraction of the pyloric sphincter.

EXAMINATION OF THE STOMACH AT OPERATION. When the abdomen is opened above the umbilicus by a vertical or transverse incision, the greater omentum is exposed as it hangs from the transverse colon. Before proceeding with the examination of the stomach itself, in a clockwise direction the liver, esophageal hiatus, spleen, left kidney, descending colon, sigmoid colon, pelvic structures, cecum, right kidney, and gallbladder area should be seen or felt. The pancreas is felt by lifting up the omentum and transverse colon and feeling along the root of its mesentery. The duodenum, pylorus and all of the stomach are then carefully examined. The walls of the normal stomach are firm; they are thicker with pyloric obstruction, and are thin and flaccid with a dilated atonic condition. The pyloric vein, which runs across the anterior surface of the pylorus, is a guide to the pyloroduodenal junction. The thickness of the pylorus and the patency of its lumen should be determined. The cardia and fundus of the stomach are somewhat difficult to see through vertical incisions because of their fixation. Wider transverse incisions and thoracoabdominal approaches (Fig. 358), provide better access to these areas for operative procedures. In searching for any lesion, all the anterosuperior surface of the stomach and the duodenum must be carefully examined. The postero-inferior surface of the stomach may be felt and seen after a small opening has been made in the gastrocolic omentum. If necessary, a large transverse opening can be made in this ligament immediately above the gastro-epiploic vessels, which will allow thorough palpation and inspection of the posterior wall of the stomach and the pancreatic area (Fig. 479). Part of the cardia can be examined through a rent in the thinnest part of the lesser omentum.

Should inspection and palpation fail to reveal a gastric lesion, yet some pathologic condition be strongly suspected, the stomach should be opened for direct internal viewing and palpation through a 3- to 6-cm. longitudinal incision at a relatively avascular space on the anterior surface. Closure of the incision may be made in a longitudinal or transverse direction, the latter having the advantage of widening the gastric lumen (Heineke-Mikulicz procedure).

REMOVAL OF XIPHOID PROCESS AS AN AID IN OPERATIONS ON THE UPPER PART OF THE ABDOMEN. The combined thoracoabdominal approach (Figs. 339, 340) gives an excellent working field in the upper part of the abdomen and lower part of the chest, and is widely used with much satisfaction. Disadvantages have to do with the opening of the pleural cavity and the postoperative need for suction tubes to keep the lung expanded. Sometimes there develops intercostal nerve pain which may be persistent. To avoid this, additional abdominal exposure may be obtained by excising the xiphoid, the transverse diameter of the wound increasing from 9 to 13 inches (Fig. 410).

GASTROSTOMY. Gastrostomy is the establish-

* Lahey and Marshall: Ann. Surg., 132:540–565, 1950.

ently, but is now combined with a subdiaphragmatic vagotomy. In dealing with duodenal ulcer, two relatively simple procedures have been used. The Heineke-Mikulicz widening principle depends upon a longitudinal incision through the pylorus with a transverse closure of the wound. In a Finney pyloroplasty an inverted U-shaped anastomosis is made between the immediate prepyloric region of the stomach and the first and second portions of the duodenum.

PARTIAL GASTRECTOMY. This is the most common operation done on the stomach for duodenal ulcer, gastric ulcer or gastric malignancy. Many procedures for restoring gastrojejunal continuity after the resection have been developed, and all are modifications of the Billroth I or II technique (Fig. 415). The anastomoses usually done today are the Billroth I-Schoemaker, Billroth II-postcolic Polya, or Billroth II-postcolic Hofmeister-Polya. Some surgeons prefer an antecolic anastomosis for the latter two procedures and obtain equally good results.

The fundamental objective in surgery on patients with duodenal and gastric ulcer is that of removing the ulcer and with it approximately three-fourths of the acid-secreting portion of the stomach (Fig. 416); this is accomplished by resecting 75 to 80 per cent of the distal part. *The middle colic artery should be avoided in* doing a gastric resection, since it lies immediately posterior to the greater curvature of the stomach and may be accidentally ligated when the branches of the gastroepiploic vessels are being ligated (Fig. 411). A possible hazard is the close relation between a chronic, deeply penetrating superior or posterior duodenal ulcer and the common bile duct. Such an ulcer is often firmly fixed to the adjacent pancreas and lower gastrohepatic ligament, so that, in excising the ulcer, injury may be done to the common bile duct and pancreatic ducts, with resulting fistulae. To avoid this error, some surgeons open and place a T-tube in the common duct to delineate its position (Fig. 417).

In dealing with carcinoma, it has been aptly said that the difficult part is not the resection of the involved organ, but the removal of its lymphatic drainage. This particularly applies to the stomach, which is richly supplied with lymphatics (Fig. 408), and malignancies which are so commonly diagnosed late that few cases are found free from lymphatic metastases. The possible extent of the latter and local pancreatic, hepatic and colonic involvement have steadily increased the radicalness of partial gastrectomy, to the point that some surgeons advocate total gastrectomy (Fig. 419) for carcinoma of the stomach whenever no distant metastases have been demonstrated.*

EXPOSURE OF LEFT GASTRIC VESSELS FOR LIGATION DURING PARTIAL OR TOTAL GASTRECTOMY. Turning up and to the left the

* Brunschwig: Radical Surgery in Advanced Abdominal Cancer. Chicago, University of Chicago Press, 1947. Lahey: Total Gastrectomy for All Patients with Operable Carcinoma of the Stomach. Surg., Gynec. & Obst., 90: 246–8, 1950.

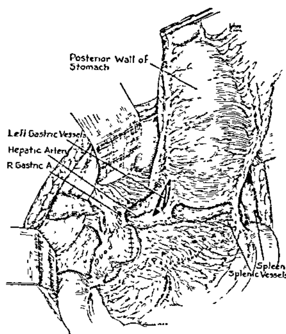


Fig. 413. METHOD OF EXPOSING THE LEFT GASTRIC VESSELS FOR LIGATION DURING PARTIAL OR TOTAL GASTRECTOMY.

(From Lahey and Marshall: Ann. Surg., 119: 300–320, 1944.)

Fig. 412. FREDET-RAMSTEDT PYLOROMYOTOMY FOR CONGENITAL PYLORIC STENOSIS.

1, Incision through the serosa over the hypertrophic muscle mass must not be carried too far distally, or the duodenum will be opened (Fig. 405). 2, Spreading of the muscle can be *carefully* done with a hemostat, and must include the most distal fibers. 3, Separation of muscle should be wide enough to allow the mucosa to bulge through the incision. 4, Omentum applied over the defect.

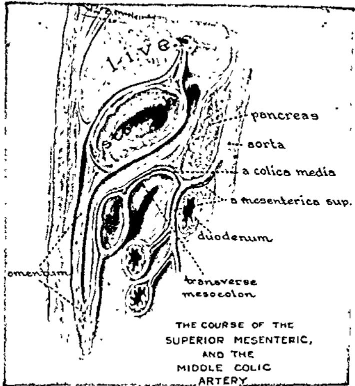


Fig. 411. COURSE OF THE MIDDLE COLIC ARTERY IN THE TRANSVERSE MESOCOLON IMMEDIATELY BEHIND THE GASTRO-EPIPLOIC VESSELS.

Accidenta ligation of the middle colic artery while dividing the gastro-epiploics may be followed by gangrene of the transverse colon. (From Babcock: Textbook of Surgery.)

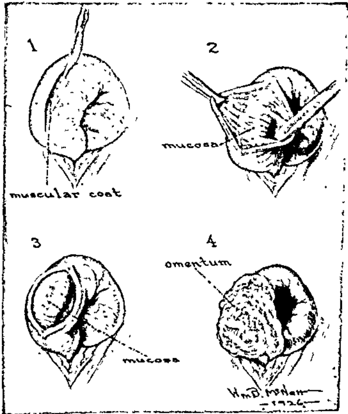


Fig. 412

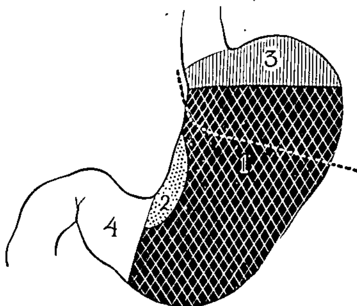


Fig. 416. DIAGRAM OF DISTRIBUTION OF PARIETAL (ACID-SECRETING) CELLS IN THE HUMAN STOMACH.

The broken line shows the level for 75 per cent resection. 1, Parietal cells maximal in this area, and rated 100 per cent. 2, Narrow area on lesser curvature has parietal cells 75 per cent. 3, Fundus parietal cells, 50 per cent. 4, Prepyloric area, 0 to 1 per cent. (Modified from Berger: Am. J. Anat., 54: 87-114, 1934.)

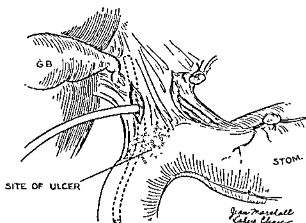


Fig. 417. T-TUBE DEFINING POSITION OF THE COMMON BILE DUCT AS A MEANS OF PROTECTING IT FROM INJURY DURING GASTRIC RESECTION FOR CHRONIC, PENETRATING DUODENAL ULCER.

(From Marshall: S. Clin North America, 29: 767-77, 1949)

iejunostomy is the method of choice for this procedure. After the abdomen has been opened by an upper abdominal vertical or transverse incision the anastomosis of the lower portion of the stomach, relatively close to the pylorus, is easily done to the jejunum a few centimeters beyond the ligament of Treitz (Fig. 420).

An *anterior* or *antecolic gastrojejunostomy* is preferred by some surgeons and selected by others when the posterior anastomosis is contraindicated by inability to mobilize the posterior wall of the stomach because of adhesions within the lesser sac, or excessive shortness or thickness of the transverse mesocolon.

VAGOTOMY. Since early in 1943 Dragstedt and his associates have used division or resection of the vagus nerves to the stomach as a method of treatment for various types of peptic ulcer, usually duodenal ulcer. The purpose of the procedure is to abolish the nervous phase of gastric secretion and thus decrease the total amount of gastric juice produced, particularly the excessive night secretion characteristic of the ulcer patient. Their original approach to

divided stomach allows a good approach to the left gastric vessels during a gastrectomy. After dividing the posterior peritoneum, they can be isolated and easily ligated free of surrounding fat (Fig. 413).

GASTROJEJUNOSTOMY. The object of gastrojejunostomy is to establish a permanent communication between the stomach and the first part of the jejunum without removing a segment of the stomach. It is now much less commonly done as an independent procedure for duodenal ulcer, usually being combined with a subdiaphragmatic vagotomy. The latter markedly reduces gastric muscle tonus and motility and is frequently associated with poor emptying of the stomach, so that a dependent outlet is needed to facilitate the passage of food.

A *posterior* or *retrocolic short-loop gastro-*

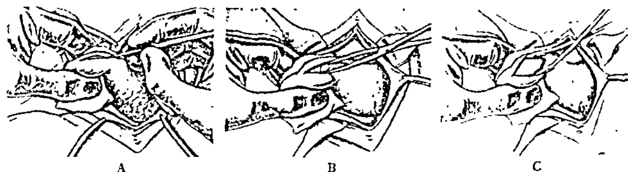


Fig. 414. METHOD OF PERFORMING A PYLOROMYOTOMY.

A, Peritoneum and outer one third to one half of the musculature incised. *B*, The remaining thickness of the musculature is separated by means of mosquito forceps. *C*, Last step in the typical procedure is spreading the entire muscular layer widely upon the base of the mucosa. (From Hayes and Goldenberg: Internat. Abst. Surg., 104: 105-38, 1955.)

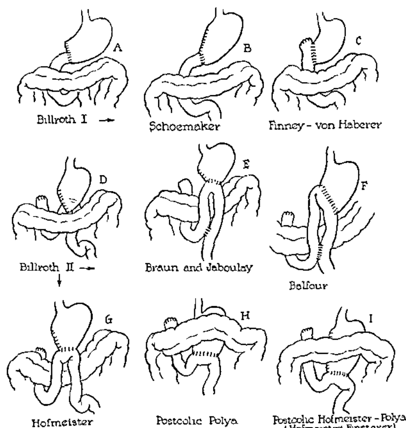


Fig. 415. VARIOUS METHODS OF ANASTOMOSING THE STOMACH TO THE INTESTINE AFTER PARTIAL GASTRIC RESECTION.

The Billroth I (*A*) and Billroth II (*D*) are the original, fundamental procedures. The others, indicated by the arrows, are modifications.

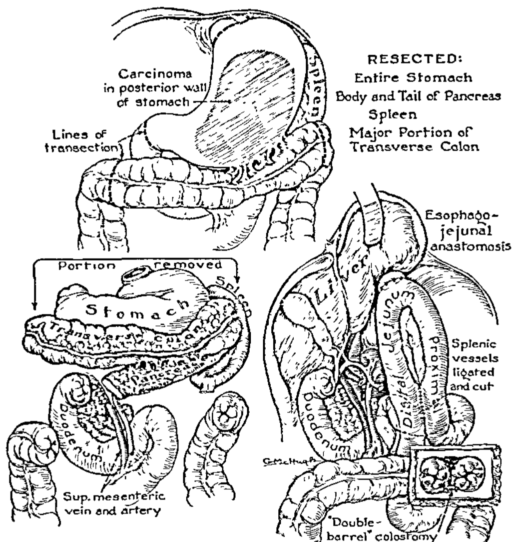


Fig. 419. RADICAL SURGERY FOR GASTRIC CARCINOMA.

Schematic representation of total gastrectomy, transverse colectomy, splenectomy, and removal of body and tail of the pancreas for primary carcinoma of the stomach with extension to neighboring viscera. Alimentary tract continuity restored by esophagojejunostomy, jejunojejunostomy and colostomy. (From Brunschwig: Radical Surgery in Advanced Abdominal Cancer. Chicago, University of Chicago Press.)

the vagus was through the thorax, but in later years they have almost entirely used a transabdominal operation (Figs. 421, 422), which has the advantage of allowing inspection and palpation of the lesion and the performance of a gastro-enterostomy or pyloroplasty, should cicatricial obstruction at the pylorus be present.

It has been repeatedly emphasized that absolutely all the vagus fibers (Fig. 422) need to be divided to obtain a satisfactory result. In careful studies of a series of cases, from 5 to 15 per cent have been found by repeated physiologic tests postoperatively to have an incomplete vagotomy.

Block Dissection of Fundal Gastric Cancer with Regional Lymph Nodes. Visalli and Grimes* have developed a method of widely excising a carcinoma of the fundal portion of the stomach and a great many of the regional lymph nodes in a block dissection which includes the body and tail of the pancreas, the spleen and the retroperitoneal lymph nodes in the celiac area. Several anatomical features make the procedure worth illustrating (Fig. 418).

* Visalli and Grimes: An Embryologic and Anatomic Approach to the Treatment of Gastric Cancer. Surg., Gynec. & Obst., 103: 401–8, 1956.



Fig. 418. OPERATIVE FIELD AFTER BLOCK DISSECTION OF PROXIMAL GASTRIC CANCER AND REGIONAL LYMPHATICS.

The operation consists in a block excision of the distal portion of the esophagus, the proximal two thirds of the stomach, the spleen, the body and tail of the pancreas, and the left half of the greater omentum, together with the regional lymphatics and nodes. A left thoraco-abdominal incision is used (Fig. 330). The diaphragm is divided towards the esophageal hiatus for a distance consistent with optimal exposure, but the esophageal hiatus is not entered.

Mobilization of the lesion is begun by incising the lienorenal ligament, allowing the spleen to be rotated medially. The embryologic fusion plane posterior to the pancreas is entered and opened by gentle blunt dissection. This dissection is carried to the point where the inferior mesenteric vein crosses behind the pancreas to join the splenic and superior mesenteric veins to form the portal vein. The greater omentum is taken off the left half of the colon by incising its filmy attachment to the large intestine.

The *en bloc* dissection which proceeds from superiorly downward is then begun by incising the peritoneum overlying the cardio-esophageal junction. Both vagus nerves are divided, allowing approximately 2 inches of esophagus to be drawn down into the abdomen. If there are no palpably enlarged lymph nodes above the diaphragm, the crura of the diaphragm are not *divided; but if the supradiaphragmatic lymphatics are involved, the dissection can be extended to* begin at the level of the inferior pulmonary vein. The lymphatic and areolar tissue overlying the diaphragmatic crura is dissected cleanly downward as the lesser omentum is divided flush with the liver hilus. The left gastric artery is ligated exactly at its origin from the celiac axis. *The splenic artery is then easily identified and similarly ligated at its origin. The splenic vein is ligated just proximal* to its confluence with the portal vein. The pancreas is divided and repaired at the junction of its body and head.

The entire specimen is then lifted out of the wound, taking care to preserve the right gastroepiploic and gastric arteries, and the stomach is divided at the junction of the body and antrum. The subpyloric and right suprapancreatic nodes overlying the gastroduodenal artery and pancreatic head, as well as the main superior mesenteric nodes, may be readily removed, since the portal vein and superior mesenteric artery now lie completely exposed.

The lateral duodenal peritoneal reflection is incised, and the duodenum is mobilized toward the midline so that the anastomosis between the esophagus and gastric antrum may be done without tension. The opening in the antrum of the remainder of the stomach is repaired. A separate stab incision is made in the anterior wall of the antrum just distal to the repaired end, and an anastomosis is made to the end of the esophagus. No attempt is made to fix the anastomosis below the diaphragm. It remains where it lies after retraction of the esophagus, usually within the esophageal hiatus. A Ramstedt or Heinecke-Mikulicz pyloroplasty is then performed. (From Visalli and Grimes: Surg., Gynec. & Obst., 103: 401–8, 1956)

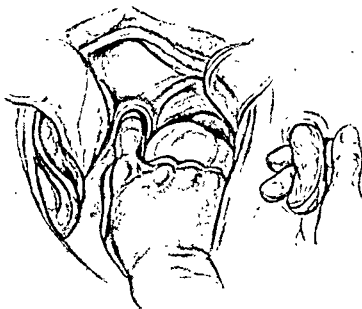


Fig. 421. TRANSABDOMINAL VAGOTOMY.

The abdomen is opened through a high left paramedian incision. The left triangular ligament is divided, and the left lobe of the liver is shown retracted medially. The peritoneum over the esophagus at the margin of the diaphragm has been divided, and the esophageal hiatus opened. The illustration shows how the finger is introduced over the esophagus into the mediastinum. By careful finger dissection the esophagus is freed and pulled downward into the abdomen for a distance of 2 to 3 inches. (From Dragstedt, Harper, Tovee and Woodward· Ann Surg., 126: 687–708, 1947.)

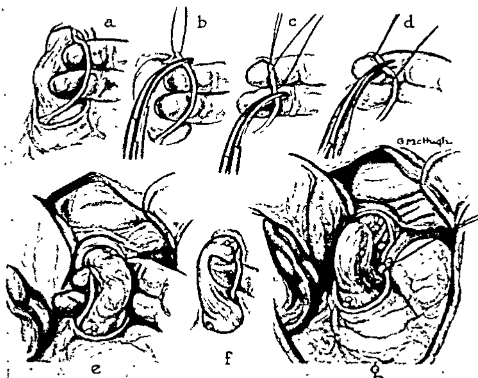


Fig. 422. TRANSABDOMINAL VAGOTOMY (CONTINUED).

The vagus nerves are separated from the esophagus by finger dissection, ligated with nonabsorbable suture material, divided, and a segment 4 to 6 cm. in length excised. Because of the tendency for poor emptying of the stomach postoperatively, a gastro-enterostomy or pyloroplasty is commonly done along with the vagotomy. (From Dragstedt, Harper, Tovee and Woodward: Ann. Surg., 126: 687–708, 1947.)

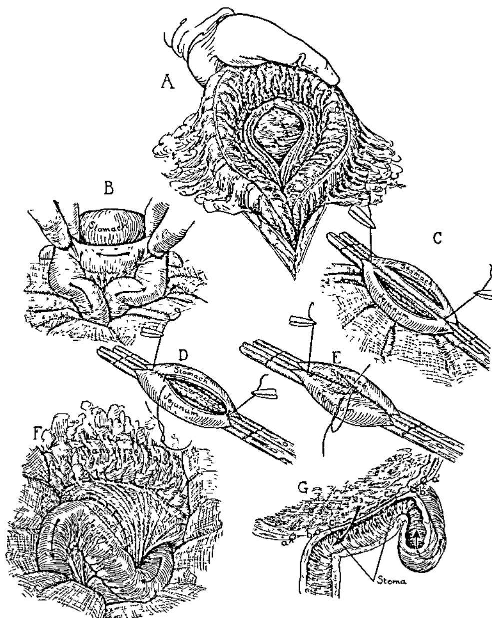


Fig. 420. POSTERIOR GASTROJEJUNOSTOMY.

A, Transverse colon brought out of the wound and a vertical opening made in an avascular area of the transverse mesocolon, usually to the left of the middle colic artery. The dependent portion of the posterior wall of the stomach close to the greater curvature is seen through this opening. *B*, An isoperistaltic alignment is made between the stomach and the jejunum 6 to 10 cm. from the ligament of Treitz. *C*, Rubber-shod clamps holding the stomach and jejunum together. Continuous submucosal suture forms the outer posterior line of the anastomosis. Lumen of stomach and jejunum opened in a longitudinal direction. *D*, Continuous over-and-over suture has formed the inner posterior line of sutures and united all layers of the stomach and jejunum. Continuous Connell suture begun to form inner line of anterior sutures uniting all layers of the stomach and jejunum. *E*, Continuous submucosal suture forms the outer anterior layer of sutures. *F*, The site of the anastomosis brought well down below the transverse mesocolon opening, the edges of which are anchored at least 2 cm. above the line of the anastomosis. *G*, Frontal section showing the dependent large stoma. From the right come alkaline bile, pancreatic juice, and succus entericus from the duodenum to mix with gastric digestive juices and food from the stomach, and then to pass along out through the distal loop of the anastomosis.

denal part of the common duct (Figs. 459, 460). The bowel then may be turned forward, downward and to the left.

The *third* or *transverse division* of the duodenum runs horizontally to the left in front of the ureter, inferior vena cava, lumbar column, and aorta (Fig. 411), and ends at the left of the third lumbar vertebra. Because of contiguity, aortic aneurysms occasionally have ruptured into the duodenum (Fig. 423). The duodenum lies behind the peritoneum in the right inframesocolic compartment, and near its termination is crossed by the root of the mesentery of the jejuno-ileum. The superior mesenteric artery runs downward over the anterior surface of the transverse division to enter the root of the mesentery (Fig. 411). Tight stretching of the artery over the segment may be responsible for certain duodenal obstructions. An anastomosis between the third or transverse portion of the duodenum and the upper jejunum will effectively by-pass such an obstruction. The pancreas is applied closely to the upper border of the segment, and is separated from it by a groove in which lies the inferior pancreaticoduodenal artery. Most of the anterior surface of the segment is overlaid by small intestine.

In operations on the kidney, or when the right colon is being mobilized for resection, the lower part of the descending and the transverse duodenum are usually exposed retroperitoneally. They must be carefully protected from damage.

The *fourth* or *ascending part* of the duodenum runs upward and slightly to the left along the left side of the spine to the duodenojejunal flexure at the root of the transverse mesocolon. At the left of the second lumbar vertebra the terminal part of the duodenum bends sharply downward, forward and to the left to form the *duodenojejunal flexure*, which is a readily recognized landmark to guide the search for obstruction in the small bowel, and to locate a loop of upper jejunum for gastrojejunostomy (p. 431). It is found by passing the hand backward to the posterior abdominal wall behind the greater omentum and palpating upward along the left of the spine until the flexure is encountered. The bend is in contact with the inferior margin of the pancreas through

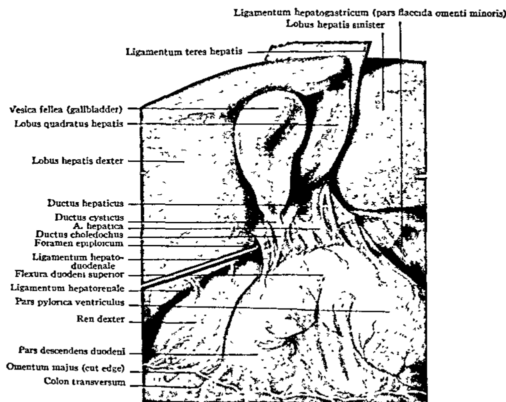


Fig. 424. FIRST PORTION OF THE DUODENUM AND ITS RELATIONS TO THE EXTRAHEPATIC BILE PASSAGES. A probe is placed in the epiploic foramen.

DUODENUM

Definition and Boundaries. The duodenum begins opposite the right side of the spine at the level of the first lumbar vertebra. It extends from the pylorus to the duodenojejunal flexure, a total length of about 25 cm., and forms a C-shaped bend, the area of which is occupied roughly by the head of the pancreas (Fig. 424). This segment is differentiated clearly from the rest of the bowel by its deep position, marked fixation, and connection with the secretory ducts of the liver and pancreas. Its lumen is larger than that of the jejunum.

Divisions and Relations. With the body in the recumbent position, the *superior* or *first part* of the duodenum (duodenal cap) passes backward and slightly upward from the pylorus to the neck of the gallbladder. With the body in the erect position this part of the duodenum passes vertically upward, and the level of the first flexure of the duodenum drops to the level of the second lumbar vertebra. The proximal 2.5 cm. are freely movable, and are invested by a continuation of the same two layers of peritoneum that enclose the stomach. The intimate relations with the gallbladder explain the adhesions between these structures and the frequency of spontaneous passage of gallstones into the duodenum (p. 464). The distal 2.5 cm. or more is covered only in front by peritoneum, so that the range of movement permitted depends upon the elasticity of the peritoneal coat. The posteromesial surface is in immediate relation with the common bile duct, portal vein and gastroduodenal artery. The inferior vena cava is separated from the segment only by a layer of areolar fusion fascia.

All this part of the duodenum lies in the supramesocolic subdivision of the peritoneal cavity (Fig. 424). The most common site of duodenal ulcer is on the anterolateral surface, and the perforation affects primarily the supracolic area. A posteromesial perforation close to the pylorus involves the omental bursa. More distal perforation results in extraperitoneal infection, which may pass upward along the vena cava to the subdiaphragmatic area and cause subdiaphragmatic (subphrenic) abscess (p. 460).

The *descending* (*vertical*) *second division* forms an acute angle with the first division and descends from the neck of the gallbladder, anterior to the hilum of the kidney and the beginning of the ureter, to the inferior duodenal flexure, by which it passes into the third division. The second division is crossed by the transverse colon, which, at this point, may or may not have a mesentery. Above the attachment of the transverse colon, the descending duodenum lies in the supramesocolic compartment; below, it lies in the infracolic area and is related to the ascending colon. Posteriorly, it is related to the right kidney, renal vessels and inferior vena cava. Its left border is related to the head of the pancreas and to the common bile duct for a short distance before its termination. The common opening of the bile and pancreatic ducts is upon the summit of a papilla about halfway down the posteromesial aspect of the division. In the anterior groove between the head of the pancreas and the descending duodenum runs the superior pancreaticoduodenal branch of the gastroduodenal artery.

This division of the duodenum is fixed definitely in position by its peritoneal relations (Figs. 403, 404, 424). By dividing the peritoneum at the right lateral edge of the upper portion of the segment (Kocher's maneuver), the descending duodenum can be mobilized so as to render surgically accessible the retroduo-



Fig. 423. RUPTURE OF AORTIC ANEURYSM INTO THIRD PORTION OF DUODENUM.

Approximately 60 such cases have been reported. (From Roll and Caudel: Arch. Surg., 72: 295–9, 1956.)

zert), when present, is the longest of the peritoneal culs-de-sac, and lies to the left of the terminal stage of the duodenum. Its presence appears to depend upon the peritoneal fold raised by the ascending branches of the left colic artery and the inferior mesenteric vein. Its mouth looks mesially, and its free crescentic margin, which may be 5 cm. long, may unite the superior and inferior duodenal fossae when they are present.

When a herniating loop of small intestine enters one of these fossae, it makes a deep sac at the expense of the posterior parietal peritoneum (intraperitoneal hernia) lying anterior to the left ureter and kidney. When strangulation occurs, care must be taken in dividing the neck of the sac lest the inferior mesenteric vein or left colic artery be injured.

Vessels of the Duodenum. The arterial supply of the duodenum is derived from the pancreaticoduodenal arteries (Fig. 407). The superior pancreaticoduodenal artery is a branch of the gastroduodenal artery from the hepatic artery, and the inferior pancreaticoduodenal artery is the first branch of the superior mesenteric artery. These arteries run in the groove between the descending and transverse divisions of the duodenum and the head of the pancreas. The anastomotic circle they form is overlaid by the transverse colon, transverse mesocolon and greater omentum, and rarely comes into surgical prominence.

Surgical Considerations

Roentgenologic Examination of the Duodenum. Roentgenologic examination of the duodenum is made after an opaque meal. The first segment, the cap or bulb, the most expanded part of the duodenum, is of special diagnostic interest. Viewed from the front, it appears as a smoothly outlined conical chamber with its base at the pyloric ring. The conical peak of the cap suggests a marked narrowing of the duodenum at that point. This apparent change in caliber results from the course of the duodenum backward, laterally and downward from the cap. The shadow of the barium-filled bulb under normal conditions is denser than the remainder of the duodenal shadow because of the more anterior position of the bulb, its greater size, and the tendency of the barium to remain in it for a short time. By reason of the



Fig. 426. DUODENAL ULCER WITH MARKED DEFORMITY OF THE FIRST PART OF THE DUODENUM. (From Boyd: Surgical Pathology.)

the root of the transverse mesocolon (Fig. 425).

FIXATION OF THE DUODENUM. In man all the duodenum, save the first portion, ultimately is anchored in position by the fusion between its peritoneum and that of the head of the pancreas to the posterior parietal peritoneum. Variations in its fusion to the posterior abdominal wall account for variations in mobility.

The duodenum is held in place to a slight degree by connections with the common bile and pancreatic ducts, as well as by the vessels and nerves running to and from it. The duodenojejunal angle is stabilized by the *suspensory muscle of the duodenum*, or *ligament of Treitz*, a bundle of involuntary muscle fibers described as running from the left pillar of the diaphragm to the angle. The right colic flexure and the fixed portion of the transverse mesocolon and mesocolon anchor the duodenum still more securely and render it doubly retroperitoneal (Fig. 424). It acquires additional fixation through the adhesion of the greater omentum to the transverse colon, mesocolon and lateral margins of the diaphragm. In its deep position the duodenum would appear to be well protected from injury, yet it sometimes is crushed and even torn against the spine in severe abdominal contusions, partly because of the rigid peritoneal fixation. A rupture of the posterior surface is difficult to recognize and to repair.

The cap or first portion of the duodenum is covered entirely by peritoneum and has considerable mobility, which is advantageous in that it offers facility for the performance of plastic operations upon the pylorus and the duodenum.

PERITONEAL DUODENAL FOSSAE. Several inconstant peritoneal recesses are found about the duodenojejunal flexure, and sometimes are responsible for strangulated intraperitoneal hernias. The pockets and peritoneal folds which form the fossae are developed to a greater or less extent, depending upon the fixation of the terminal duodenum (Fig. 425).

The *superior duodenal fossa* lies behind the superior duodenojejunal fold, the concave free border of which is directed inferiorly. This fold extends to the left from the flexure for about 2.5 cm. The upper segment of the inferior mesenteric artery may run in the free margin of the fold. The mouth of the fossa looks downward, while its cavity passes upward toward the pancreas. The *inferior duodenal fossa* (of Jonnesco) has its apex or blind extremity directed downward to the right, its depth being about 2.5 cm. The inferior duodenojejunal fold, forming the anterior wall, stretches from the left side of the duodenum to the left of the aorta and spine. The upper or free edge of the fold contains no vessels of consequence. The *paraduodenal fossa* (of Land-

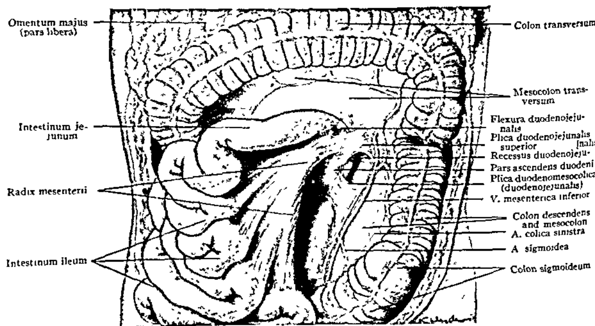


Fig. 425. DUODENOJEJUNAL FOLDS AND FOSSAE.

Attention is called to the relation between the inferior mesenteric vessels and the superior duodenojejunal fold.

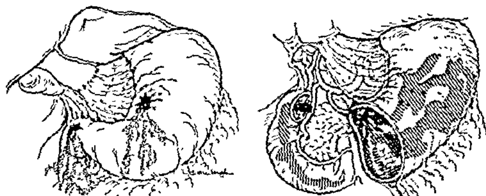


Fig. 428. THE ANATOMIC REASON WHY MASSIVE BLEEDING MAY OCCUR FROM POSTERIORLY SITUATED PEPTIC ULCERS, WHILE THE ANTERIOR ULCER SELDOM BLEEDS PROFUSELY.

For the posterior gastric ulcer the left gastric artery is commonly involved, while for the posterior duodenal ulcer the gastroduodenal artery is the usual source of massive bleeding. Anterior peptic ulcers lie on relatively muscular portions of the stomach and duodenum. Anterior ulcer perforations commonly present into the free peritoneal cavity. (From Allen and Oberhelman, Jr.: Surgery, 37: 1019–28, 1955.)

Acute perforation is a common complication of a duodenal ulcer and requires immediate closure (Fig. 427). Perforation often occurs in patients giving no previous history of the ulcer.

ANATOMY OF THE BLEEDING ULCER. The massively bleeding peptic ulcer is usually located posteriorly, where it erodes a major artery. For the gastric ulcer, branches of the left gastric artery are usually involved, while for the duodenal ulcer the gastroduodenal artery is the common source of bleeding (Fig. 428).

Conversely, the acutely perforating peptic ulcer is generally situated anteriorly (Fig. 428), where it is free to pour food and digestive juices into the peritoneal cavity. Rarely is such an ulcer the cause of massive bleeding.

Pathologic conditions favoring the continuance or recurrence of hemorrhage from an eroded artery are arteriosclerotic changes producing degenerative and inelastic walls, or an artery whose wall is held open by being embedded in the hard scar of a chronic ulcer.

HERNIAS ABOUT THE DUODENOJEJUNAL FLEXURE. When the peritoneal fixation of the duodenojejunal flexure is less than normal, fossae are present (Fig. 425) which permit enlargement by peritoneal cleavage. The practical significance of these fossae lies in the fact that they furnish sites for the development of intraperitoneal hernias. A large amount of the small intestine may enter the sac. The diagnosis of an intraperitoneal hernia is often difficult; but once the hernia is found, repair is simply the emptying of the sac and firm suturing of the entrance.

DUODENAL DIVERTICULA. Duodenal diverticula, both congenital and acquired, have been recognized as occasional and usually inconsequential findings on x-ray examination or at autopsy. Most of them are located in the descending portion of the duodenum, often close to the ampulla of Vater, and buried in the substance of the pancreas. They may vary in size from 1 to several centimeters in length and usually have no circular or longitudinal coats, the wall being made up of the duodenal mucosa and submucosa.

Some of these diverticula cause symptoms varying from mild dyspepsia to real pain. The best differential aid is barium x-ray studies showing a six-hour retention and no other duodenal, gastric or biliary tract disorder possibly responsible for the symptoms. If dietary management fails to give relief, surgical excision of the diverticulum is indicated. At operation, intubation of the common bile duct with a T-tube helps to locate and spare that structure from harm if the diverticulum to be excised is close by (Fig. 417).

ATRESIA AND STENOSIS. Congenital atresia of the small and large intestines is a malformation of uncommon occurrence in which there is complete obstruction of the alimentary tract (Fig. 429). Owing to consequent dehydration and starvation, or to rupture of the blind intestine, death supervenes, in most cases, during the first week of life (Gross). Cases of narrow-

rapid transit of the duodenal contents through the second, or descending, portion of the duodenum, that part often is not well visualized. The duodenal cap can be shifted about to some extent by manipulation through the abdominal wall, but the other divisions are fixed and respond but slightly to passive movement.

DUODENAL ULCER. Ulcers of the duodenum, in the majority of instances, are located within 5 cm. of the pylorus, and therefore in the mobile part of the bowel (Fig. 426). They occur most often on the anterior wall toward the right. Fluid from a perforated ulcer has a tendency to localize in the right subhepatic space, whence it is often guided laterally and down the right paracolic gutter or along the obliquity of the small intestinal mesenteric attachment to the ileocecal region. Perforation sometimes causes a subdiaphragmatic abscess. Posterior duodenal or gastric ulcers tend to penetrate deeply, and the floor of the ulcer may be formed by the under surface of the liver or pancreas, adhesions having been formed previously between the opposed serous surfaces. The proximity of the duodenum to the gallbladder explains the frequency with which adhesions are found in patients having had attacks of cholecystitis and also explains the ulceration of the gallstones into the duodenum. Cicatrization of an extensive duodenal ulcer frequently causes stenosis of the bowel with subsequent dilatation of the stomach.

The rich blood supply of the duodenum, with vessels lying superiorly, posteriorly and inferiorly (Figs. 407, 428), readily explains why ligation of a few arteries is an unsatisfactory treatment for severe bleeding duodenal ulcer. Partial gastrectomy with resection of the ulcer is the only safe way of handling such a pathologic condition.



Fig. 427. CLOSURE OF PERFORATED DUODENAL ULCER.

Spinal anesthesia is commonly used because of muscle spasm, and to minimize dissemination of duodenal contents by reducing respiratory efforts and diaphragmatic movements. An adequate approach may be obtained through a right upper quadrant paramedian incision. In order not to narrow the hard, indurated duodenum, the perforation is not closed, but covered over by 3 seromuscular sutures holding an attached piece of omentum in place as an omental graft. (From Orr: Operations of General Surgery; Graham: Surg., Gynec. & Obst., 64: 235-8, 1937.)

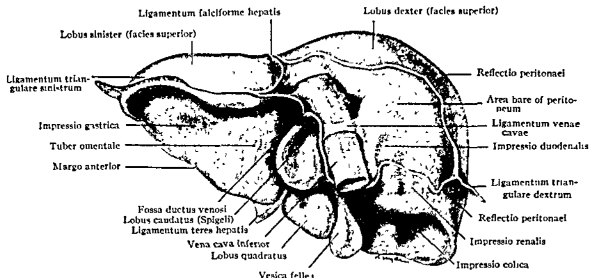


Fig. 432. POSTERIOR VIEW OF THE LIVER.

Demonstrating the bare area and the peritoneal reflections which suspend the liver from the diaphragm.

tends into the left hypochondrium and downward into the right lumbar region. It lies immediately beneath the diaphragm, and is covered by the ribs over the greater part of its lateral surface; only a small part of its anterior surface is in contact with the anterior abdominal wall.

SURFACES AND RELATIONS. The *convex* or *anterosuperior surface* of the liver is molded to both halves of the diaphragm (Fig. 431). It is almost hidden at the costal margin, save in the subcostal angle, where it contacts the anterior abdominal wall and can be examined by palpation and percussion (Figs. 433, 435).

The convex surface of the right lobe is in relation with the right lung and pleura. This explains the erosion of hepatic cysts and abscesses through the diaphragm into the pleural cavity and right lung, and the evacuation of their contents into the bronchi. To reach a liver abscess high on the convex surface, the pleura, diaphragm and peritoneum must be traversed. When tumors and abscess occur in the anterior part of the convex surface, they usually distend the surface sufficiently to bring it into contact with the abdominal wall over a considerable area, thus making themselves surgically accessible without extrapleural resection of the costal margin. Violin-string adhesions between the parietal surface of the liver and the adjacent anterior abdominal wall and the diaphragm not infrequently occur in patients with coincident residual gonococcal tubal disease (Curtis).

The convex surface of the left lobe is small and has little relation to the anterior abdominal wall.

The *right lateral surface* lies just beneath the costal margin in the midaxillary line. It rests against the diaphragm and is related indirectly to the thin edge of the base of the right lung, to the costodiaphragmatic pleural recess, and to the thoracic wall from the seventh to the eleventh ribs, and is covered entirely by peritoneum. .

The peritoneum of the superior surface iy not continued over the *posterior surface*, but is reflected to the diaphragm to form the coronars ligament (Figs. 431, 432). The peritoneum of the inferior surface of the right lobe is reflected to the kidney (posterior layer of the coronary ligament), so that the right half of the posterior surface of the liver is devoid of peritoneal covering and is in direct contact with the diaphragm. It is known as the "bare area," and is contained within the reflections of the coronary ligament, the lateral edges of which form triangular ligaments (Figs. 431, 432, 434). This is the site of extraperitoneal subdiaphragmatic abscesses which occur from the upward spread of retroperitoneal abscesses on the right side of the abdomen.

SURFACE ANATOMY OF THE LIVER. Owing to the deep location of the liver under the arching vault of the diaphragm, its surface projection is indicated by an outline confined mainly to the thorax, but including a small portion of the epigastrium (Figs. 433, 435). It is important of know accurately the upper and lower limits to

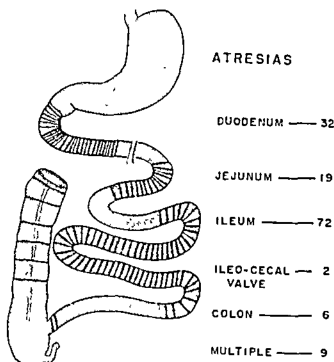


Fig. 429. POSITIONS OF ATRESIA IN 140 CASES.

Diagrammatized record of cases treated surgically at the Boston Children's Hospital. It is to be noted that in approximately 88 per cent of the cases (123 of 140), atresia occurred in the small intestine. (From Gross: The Surgery of Infancy and Childhood.)

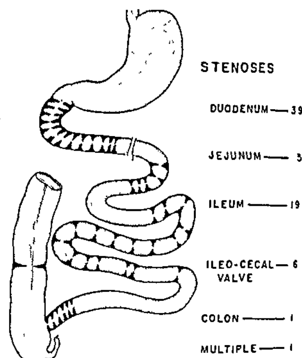


Fig. 430. POSITIONS OF STENOSIS OF THE INTESTINAL TRACT IN 71 PATIENTS.

Schematized record of cases (infants and children) treated surgically at the Boston Children's Hospital. As in cases of atresia (Fig. 429), the pathology occurred in the small intestine in approximately 88 per cent of instances (63 of 71). Ages: between the first and 9 years of life. (From Gross: The Surgery of Infancy and Childhood.)

ing of the intestinal lumen, likewise uncommon, belong in the same category in respect to developmental causation. However, the most frequent site is the duodenum (Fig. 430), whereas the predilective site for atresia is the ileum (Fig. 429). Side-to-side anastomosis is the surgical procedure of choice (Gross).

LIVER

DEFINITION AND BOUNDARIES. The liver, by far the largest glandular organ in the body, is located mainly in the upper abdomen on the right side (Figs. 431, 432). It occupies the right hypochondriac and epigastric regions, and ex-

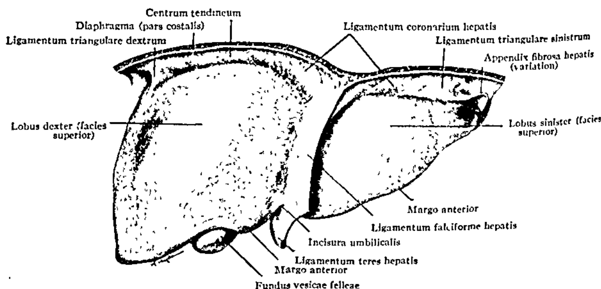


Fig. 431. ANTEROSUPERIOR SURFACE OF THE LIVER AND ITS CONNECTION WITH THE DIAPHRAGM.

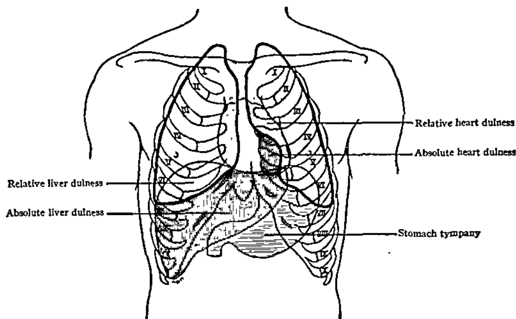


Fig. 435. PERCUSSION OUTLINES OF THE HEART, LIVER AND STOMACH.

Vena cava inferior
V. hepatica
V. coronaria ventriculi
A. coeliaca
V. pylorica
V. portae
V. gastroepiploica dextra
V. pancreaticoduodenalis
V. mesenterica superior
V. colica dextra
V. ileocolica
V. appendicularis
Oesophagus
V. lienalis
V. gastroepiploica sinistra
V. mesenterica inferior
V. colica sinistra
V. sigmoidea
V. haemorrhoidalis superior
HEPAR
DIAPHRAGMA
PANCREAS
DUODENUM
COLON DESCENDENS
COLON ASCENDENS
COLON SIGMOIDEUM

Fig. 436. VEINS OF THE PORTAL SYSTEM.

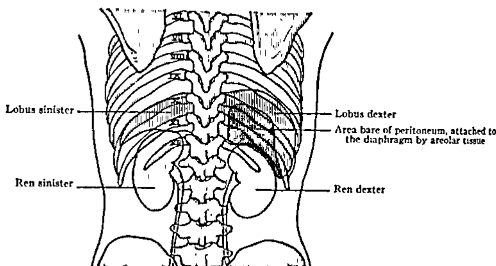


Fig. 433. PROJECTION OF THE LIVER ON THE POSTERIOR SURFACE OF THE TRUNK.

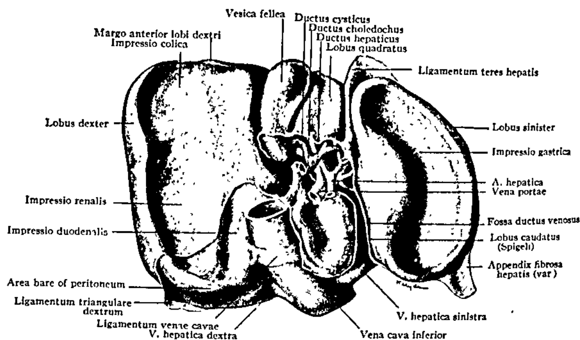


Fig. 434. INFERIOR SURFACE OF THE LIVER.

the normal liver in order to determine an increase or decrease in size, or a change in level. The limits are determined by the physical diagnostic methods of palpation and percussion. It is difficult to determine the upper and lower boundaries with precision, because the lower edge of the lung overlaps the liver above, and the lower thin edge of the liver overlaps the stomach and intestine below.

The area within the epigastrium where the liver is accessible to palpation is important, especially when the organ is enlarged. The lower margin rises and falls during respiration and affords a useful diagnostic sign in the differentiation of obscure abdominal tumors which may or may not be attached to it. When the gallbladder is enlarged, the outline of its fundus sometimes can be made out distinctly, especially in thin-walled persons.

When the liver enlarges upward, the base of the lung rises with the diaphragm, but the depth of the pleural recess is essentially unchanged. This disposition is important in surgery of the liver, since it happens frequently that the most direct route to a hepatic abscess or cyst in the right lobe is by way of the thorax. In such cases the lung is displaced upward out of the pleural recess, and the diaphragm lies in contact with the thoracic wall to an abnormal extent. To reach the liver through the dia-

phragm, the pleural recess usually is opened. This constitutes the transpleural route for hepatotomy.

BLOOD VESSELS OF THE LIVER. The liver is supplied with blood from both the hepatic artery and the portal vein. After circulating through the liver the blood is returned to the inferior vena cava by the hepatic veins (Fig. 436).

The *hepatic artery proper* (Fig. 467) is one of the trunks of trifurcation of the celiac artery. It is directed at first almost horizontally from left to right behind the peritoneal floor of the lesser sac. Destruction of the right or left terminal branches of the hepatic artery does not cause necrosis of the corresponding liver area supplied, since an accessory system of hepatic arteries supplements these vessels.

The *portal vein* carries to the liver blood which has passed through the capillaries of the whole abdominal alimentary tube, the pancreas, spleen and gallbladder (Figs. 436, 439). It is a thick trunk about 6.5 cm. long, formed behind the head of the pancreas by the union of the splenic and superior mesenteric veins. Numerous variations occur in its formation, which may be important to the operation of splenorenal anastomosis (Fig. 439). It ascends at first behind the first division of the duodenum, but emerges between the two layers of the gastrohepatic omentum as far as the hepatic porta. It is accompanied closely by the bile ducts and also by the hepatic artery, whose interrelations vary greatly (Figs. 437, 438, 455 to 457).

Infections which localize in the wall of the portal vein cause *portal phlebitis* or *pylephlebitis*. If this lesion progresses to an occlusive thrombosis, embarrassment of the portal circulation supervenes, with consequent ascites and the development of an accessory portal circulation.

The *hepatic veins* carry the blood away from the liver by draining into the inferior vena cava in its groove on the posterior aspect of the organ (Figs. 434, 436).

ACCESSORY PORTAL SYSTEM. There are definite natural channels of anastomosis between the portal and caval systems of veins, but they do not function unless obstruction to the portal vein, either in its intraperitoneal or intrahepatic course, so demands. These communications constitute a portal system accessory to the main trunk. Essentially, they are anastomoses between the portal radicles of the gastrointestinal and hepatic territories and the caval radicles of the surrounding structures.

Chief among the anastomosing channels between the portal and hepatic systems are the paraumbilical veins, which run in the falciform ligament of the liver and unite the left branch of the portal vein with the epigastric venous network of the abdominal wall (caval system). These veins, when enlarged, form a varicose network under the skin of the anterior abdominal wall known clinically as the "caput Medusae." Occasionally a single vein may attain the size of the small finger and run directly between the liver hilum and the epigastric vein at the umbilicus. Veins about the gallbladder, lesser omentum and lesser curvature (portal system veins) sometimes connect with the paraumbilical veins and thereby with the caval system of the anterior abdominal wall. These same portal radicles sometimes anastomose with the diaphragmatic and intercostal tributaries of the azygos veins (caval system).

At the distal end of the esophagus the left gastric veins (portal system) communicate in the submucous layer with the esophageal veins (caval system). In portal obstruction the esophageal veins may become dilated and produce large varices which project into the esophageal mucosa. These veins, being almost unsupported, may rupture when the patient apparently is in excellent health, and result in a rapidly exsanguinating hemorrhage. Passage of a stomach tube, or any other form of esophagogastric instrumentation, is an exceedingly dangerous practice in any patient who may have esophageal varices.

There are anastomoses about the lower rectum between the superior hemorrhoidal

cystic arteries arises low as a branch of the gastroduodenal, coursing upward, it crosses in front of the common bile duct and the portal vein. The second cystic artery, much the shorter of the 2, is a branch of the left ramus; turning sharply to the right, and crossing in front of the left hepatic duct, it supplies the left half of the gallbladder and fossa. *h*, A rare example of dual cystic arteries, fused distally (at arrow) to form a single terminal trunk, and in this way to contribute to an arterial circle around the hepatic duct. *i*, The cystic artery is derived, in the familiar way, from the right ramus of the proper hepatic artery. A large accessory hepatic duct from the right lobe of the liver enters the common bile duct just distal to the point of fusion of the cystic and hepatic ducts. *j*, In this specimen the cystic duct enters the right hepatic duct. The cystic artery arises from the point of division of the proper hepatic artery; it crosses in front of the right and left hepatic ducts to reach the gallbladder. (From Anson: Quart. Bull., Northwestern Univ. M. School, 30: 250-59, 1956. Redrawn from Daseler, Anson, Hambley and Reimann. Surg., Gynec. & Obst., 85 47-63, 1947)

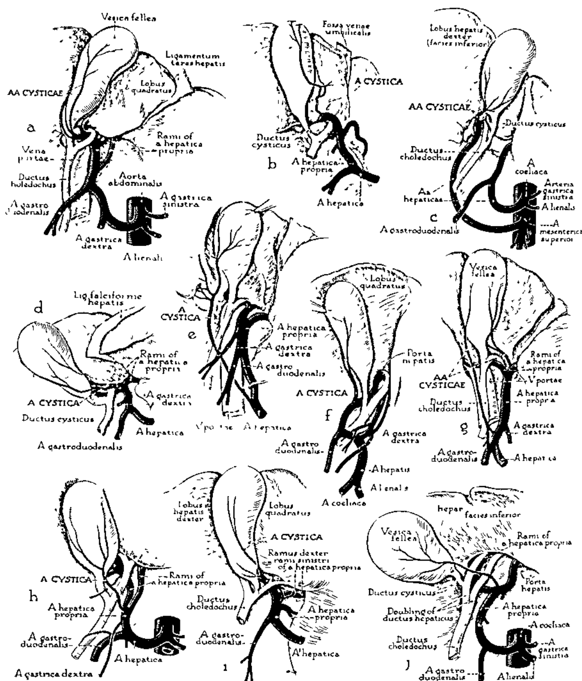


Fig. 437. CONSTITUENTS OF THE HEPATIC PEDICLE. VARIATIONS ENCOUNTERED IN A STUDY OF 500 LABORATORY SPECIMENS.

a, The larger of 2 cystic arteries arises from the right ramus of the hepatic artery proper after the latter has passed behind the hepatic duct. *b*, The cystic artery in this instance is a branch of the right ramus of the hepatic artery proper, which crosses in front of the hepatic duct. *c*, Here, in the absence of a regular hepatic artery, the artery to the left lobe of the liver arises as a branch of the celiac axis. The artery to the right lobe, derived from the superior mesenteric artery, passes obliquely upward and to the right, first posterior to the common bile duct, then to the right of the duct; just before entering the right lobe of the liver, it gives rise to a large cystic branch to the hepatic surface of the gallbladder. The artery to the left lobe, derived from the celiac, contributes no cystic branch. *d*, The cystic artery, originating from the left ramus of the proper hepatic artery, then courses to the right, in front of the hepatic duct. *e*, An example of an unusually long cystic artery derived from the proximal portion of the hepatic artery (not from the hepatic proper). Ascending to the right, the artery passes behind the common bile duct and portal vein. It gives rise to several small twigs to the right hepatic lobe before eventually reaching and supplying the gallbladder and the tissues in the fossa. *f*, Here the hepatic artery divides at a point distant from the porta; as a consequence, the rami are exceptionally long. From the right ramus a cystic artery ascends to the gallbladder, and a gastroduodenal descends. From the left ramus 3 arteries ascend to the left lobe of the liver, and a right gastric descends. Because of these arrangements the blood supply of the stomach is a constituent of the hepatic pedicle. *g*, One of a pair of

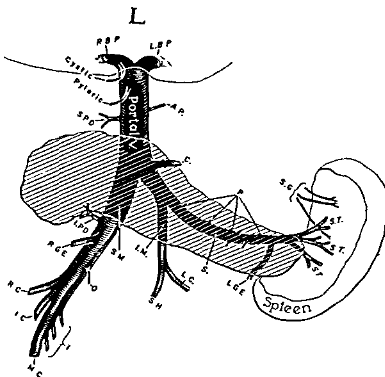


Fig. 439. THE EXTRAHEPATIC PORTAL SYSTEM OF VEINS.

The termination of each vein is shown as it was encountered most frequently in 92 dissections. The pancreas is represented by the shaded area.

Abbreviations: *A.P.*, accessory pancreatic vein; *C.*, coronary vein; *Cystic*, cystic vein; *I.*, intestinal veins; *I.C.*, ileocolic vein; *I.M.*, inferior mesenteric vein; *I.P.D.*, inferior pancreaticoduodenal vein; *L.*, liver; *L.B.P.*, left branch of portal vein; *L.C.*, left colic vein; *L.G.E.*, left gastro-epiploic vein; *M.C.*, middle colic vein; *O.*, omental vein; *P.*, pancreatic veins; *Pyloric*, pyloric vein; *R.C.*, right colic vein; *R.G.E.*, right gastro-epiploic vein; *R.B.P.*, right branch of portal vein; *S.*, splenic vein; *S.G.*, short gastric veins; *S.H.*, superior hemorrhoidal vein; *S.M.*, superior mesenteric vein; *S.P.D.*, superior pancreaticoduodenal vein; *S.T.*, splenic trunks. (From Douglass, Baggenstoss and Hollinshead: Surg., Gynec. & Obst., 91: 562–76, 1950.)

compensation in portal obstruction. Since venous connections arise when inflamed abdominal viscera become adherent to the abdominal walls, it has been proposed, in an uncompensated portal block, to establish an artificial connection between the omentum or other abdominal structure and the abdominal wall. The apposed peritoneal surfaces of the liver and spleen (portal circulation) and those of the diaphragm and anterior abdominal wall (caval system) are irritated to encourage the formation of adhesions and thus facilitate an artificial anastomosis (Talma-Morison operation). In addition, the greater omentum (tributary to the portal system) may be sutured to the peritoneum of the anterior abdominal wall (tributary to the caval system).

Surgical Considerations

LIGATION OF THE HEPATIC ARTERY AND REMOVAL OF THE CELIAC AXIS. Recently, successful ligation of the hepatic artery for portal cirrhosis and complete excision of the celiac artery and the gastric set of lymphatic glands and vessels for carcinoma of the stomach (after integrity of the superior mesenteric artery had been established) have served to demonstrate empirically that there exist vascular channels which provide for compensatory collateral circulation. Possible channels, to a total of twenty-six, have been demonstrated impressively by Michels, from a study of 200 dissections (Figs. 440, 441). However, owing to the degree to which vascular patterns vary, it must be borne in mind that relatively few of the total number of collateral pathways demonstrated could be relied upon to establish an adequate compensatory supply to the liver (Michels).*

OPERATIVE TREATMENT OF PORTAL HYPERTENSION. In several disease conditions the portal vein becomes blocked, and the obstruction may be intrahepatic or extrahepatic. Portal hypertension of varying degree then develops, but pressures encountered are frequently three to five times greater than normal. To circumvent the obstruction, three *collateral circulations may develop between the portal system and the general venous system.* One is in the gastrointestinal tract where glandular epithelium unites with squamous epithelium, i.e., at the cardia and at the anus. At the latter site the middle hemorrhoidal veins connect with the inferior vena cava through the inferior hemorrhoidals. The gastric cardiac veins provide an outlet by way of the esophageal veins to the azygos vein to the superior vena cava. A second venous collateral may occur at the site of the obliterated fetal circulation, the paraumbilical veins in the round ligament of the liver, which

* See Nicholas A. Michels: Blood Supply and Anatomy of the Upper Abdominal Organs, with a Descriptive Atlas. Philadelphia, J. B. Lippincott Company, 1955.

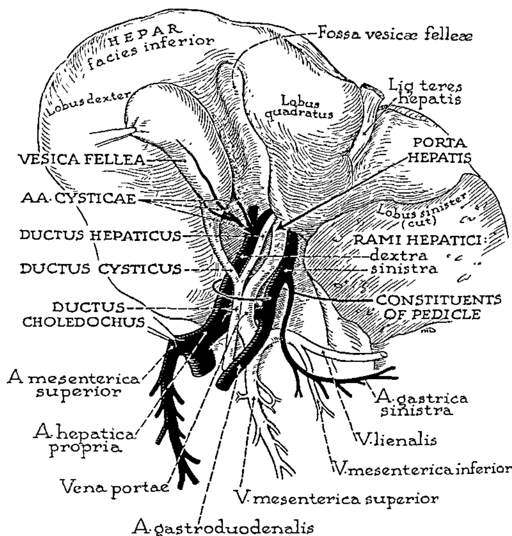


Fig. 438. CONSTITUENTS OF THE HEPATIC PEDICLE IN A STRIKINGLY ABERRANT CASE.

The arteries arise from the superior mesenteric, not from the celiac. The proper hepatic artery (to the reader's left) is exceptionally short; its 2 branches or divisions (the right and left hepatic rami to the lobes of the liver) are, therefore, unusually long; they ascend to the porta of the liver along the hepatic duct and common bile duct on the specimen's right, and along the portal vein on the left. The cystic artery, from the right ramus, divides quickly, its divisions going to the upper and lower surfaces of the gallbladder. These features, combined, produce a highly complex set of interrelationships in the hepatoduodenal ligament, differing greatly from the arrangement classically presented. Thus, superiorly (that is, near the liver), the succession of structures is as follows (from the specimen's right to left): the cystic duct; the right ramus of the hepatic duct; the portal vein; the left ramus of the hepatic artery proper; the left gastric artery. Inferiorly (near the duodenum), the succession of structures is as follows: the right ramus of the hepatic artery proper; the common bile duct; the portal vein; the left ramus of the hepatic artery proper (which, ascending within the hepatic pedicle, crosses behind the common bile duct and portal vein to a position parallel to that of the vein); the gastroduodenal artery; and, lastly, the continuation of the left gastric artery. (From Anson: Quart. Bull., Northwestern Univ. M. School, 30: 250–59, 1956.)

veins (portal system) and the middle and inferior hemorrhoidal veins (caval system). The degree of communication is variable, since, in many cases of portal obstruction, hemorrhoidal varices are not evident. In the region of the bare area of the liver are collateral paths between the veins of the liver (portal system) and the veins of the diaphragm (caval system). The veins of Retzius unite the radicles of the splenic and mesenteric trunks of the portal with the branches of the inferior vena cava. To this group belong whole collections of retroperitoneal veins lying about the abdominal viscera which are fixed to the abdominal wall and diaphragm. These viscera are the liver, suprarenal bodies, duodenum, pancreas and the ascending and descending portions of the colon. These veins divert blood from the portal circulation into the following caval tributaries: *lower intercostal, diaphragmatic,* lumbar, iliolumbar, epigastric, and circumflex iliac veins.

These anatomic connections between the two venous systems seldom suffice to effect

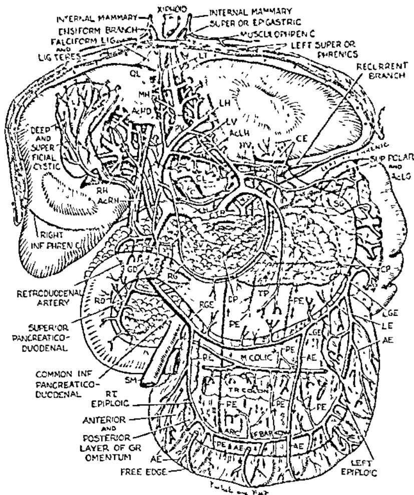


Fig. 441. POSSIBLE COLLATERAL ARTERIAL PATHWAYS TO THE LIVER. A COMPOSITE OF PATTERNS FOUND IN DISSECTIONS OF 200 CADAVERS.

I Routes through hepatic arteries arising from sources other than the common celiac hepatic trunk. Accessory left hepatic (*AcLH*) from left gastric (*LG*); accessory right hepatic (*AcRH*) from superior mesenteric (*SM*).

II. Nonhepatic routes capable of connecting with branches of severed hepatic arteries: 1, Infragastric via right and left gastroepiploics (*RGE*⇄*LGE*) and gastroduodenal (*GD*) to the right, and short gastrics (*SG*) to the left. 2, Supragastric, via right and left gastrics (*RG*⇄*LG*). 3, Infracolic, via arc of Barkow in posterior layer of the great omentum, blood may be routed directly into the gastroduodenal (*GD*) through right gastroepiploic (*RGE*) and right epiploic (*RE*) in type I; indirectly into it via posterior epiploic (*PE*), transverse pancreatic (*TP*) and its connections in type II. Left limb of arc is always made by the left epiploic (*LE*). 4, Paraesophageal hepatogastric. Cardio-esophageal (*CE*) branches from the left gastric (*LG*) and splenic (*S*) via its short gastrics (*SG*) unite with similar branches from accessory left hepatic (*AcLH*). 5, Retroesophageal. Recurrent branch of left inferior phrenic gives off cardio-esophageal (*CE*) branches that unite with those derived from accessory left hepatic (*AcLH*), short gastrics (*SG*), and accessory left gastric (*AcLG*). 6, Transpancreatic. Blood leaving the splenic (*S*) through the dorsal pancreatic (*DP*) or a. pancreatica magna (*PM*) and caudal pancreatic (*CP*), or coming from the arc of Barkow through a posterior epiploic (*PE*) enters the transverse pancreatic (*TP*) via which it may course into the superior pancreaticoduodenal (*SPD*), right gastroepiploic (*RGE*) or gastroduodenal (*GD*) to reach the hepatic trunk (*H*).

III. Routes over arteries outside of the celiac blood supply. 1, Superior mesenteric (*SM*) via the inferior pancreaticoduodenal and the anterior and posterior pancreaticoduodenal arcades respectively made by the retroduodenal (*RD*) and superior pancreaticoduodenal (*SPD*) branches of the gastroduodenal (*GD*) 2, Superior mesenteric via its transverse pancreatic (*TP*) branch, which may connect with the *SPD*, *RGE* or *GD*. 3, Inferior phrenics coursing in the diaphragm unite with branches of the hepatic at attached areas of liver. Cardio-esophageal (*CE*) branches of the recurrent branch of the left inferior phrenic anastomose with subcapsular branches of the hepatic in fossa for ligamentum venosum. 4, Superior phrenic from the terminal branches of the internal mammary, i e., superior epigastric and musculophrenic, communicate with branches of hepatic in diaphragm. 5, Ensiform branch of the internal mammary coursing in the falciform ligament and ligamentum teres unite with terminal falciform branches given off by the left (*LH*) and middle hepatic (*MH*). 6, Vasa vasorum. An arteriole derived from the right inferior phrenic courses upward to liver along inferior vena cava (*IVC*). 7, Supply along the biliary ducts by arteriole derived from the retroduodenal (*RD*).

(Key to lettering as follows: *AE*, anterior epiploic; *CTr*, celiac trunk or axis; *CL*, caudate lobe; *PE*, posterior epiploic; *PV*, portal vein; *SV*, splenic vein; *QL*, quadrate lobe.) (From Michels: Cancer, 6: 708-24, 1953.)

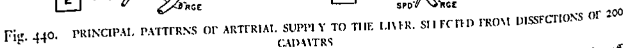


Fig. 440. PRINCIPAL PATTERNS OF ARTERIAL SUPPLY TO THE LIVER. SELECTED FROM DISSECTIONS OF 200 CADAVERS

A, Typical textbook pattern of the hepatic artery with its 3 hepatic branches, right, left and middle. *B*, Hepatic gives off right hepatic and middle hepatic; left hepatic is replaced from left gastric. *C*, Hepatic gives off left hepatic and middle hepatic; right hepatic is replaced from superior mesenteric. *D*, Hepatic gives off right, middle and left hepatic; an accessory left hepatic from left gastric. *E*, Hepatic gives off right, middle and left hepatic; an accessory right hepatic from superior mesenteric. *F*, Entire hepatic trunk arises from superior mesenteric, there being no celiac hepatic.

(*AcHD*, accessory hepatic duct; *AcLG*, accessory left gastric; *AcLH*, accessory left hepatic; *AcRH*, accessory right hepatic; *C*, cystic artery; *CBD*, common bile duct; *CD*, cystic duct; *CE*, cardio-esophageal branches; *CL*, caudate lobe; *DP*, dorsal pancreatic; *Fis*, fissure under gallbladder; *GD*, gastroduodenal; *H*, hepatic; *HD*, hepatic duct; *LH*, left hepatic; *MCOL*, middle colic; *MH*, middle hepatic; *P*, inferior phrenic; *ReLH*, replaced left hepatic; *ReRH*, replaced right hepatic; *RD*, retroduodenal; *RG*, right gastric; *RGE*, right gastroepiploic; *RH*, right hepatic; *S*, splenic; *SD*, supraduodenal; *SPD*, superior pancreaticoduodenal; *SM*, superior mesenteric; *TP*, transverse pancreatic.) (From Michels: Cancer, 6: 708-24, 1953)

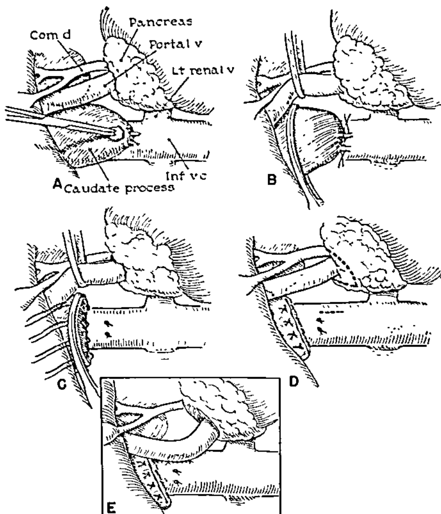


Fig. 443. RESECTION OF CAUDATE PROCESS OF LIVER AND SIDE-TO-SIDE PORTACAVAL SHUNT.

In certain patients hypertrophy of the caudate process may encroach upon the site for the anastomosis and should be resected. As noted in *B*, it is necessary to ligate 2 or more pairs of minute veins running from the caudate process to the vena cava. These are frequently unrecognized and may be torn, giving rise to troublesome hemorrhage in an area difficult to control. Once the caudate process has been freed from the underlying vena cava, it can be cross-clamped and resected. Hemostasis is achieved by multiple vertical mattress sutures. (Blackmore and Voorhees, from Madden: Atlas of Technics in Surgery. In Press. Appleton-Century-Crofts, New York.)

lation. The results were usually unsatisfactory. In 1945 Whipple and Blakemore* developed the method of producing portacaval shunts to effect a reduction of blood pressure in the portal system in cases of portal hypertension. A nonsuture technique of blood vessel anastomosis was devised whereby a cuff of an artery or vein folded back on a vitallium tube could be inserted into another vessel, forming an intima-to-intima anastomosis. At present the anastomoses are mainly done by suture methods, but the principle of the procedure remains unaltered.

The key to a successful portacaval shunt is a rapidly moving stream of blood. A high rate of flow can be achieved when the pressure within the portal system is high and the pressure within the vena cava or renal vein is low, thereby establishing a satisfactory pressure gradient. A high rate of flow can be further assured by minimizing peripheral resistance, particularly in the portal or the splenic vein. Angulation or constriction of either of these

* Whipple: The Problem of Portal Hypertension in Relation to the Hepatosplenopathies. Ann. Surg., 122: 449–75, 1945; Blakemore and Lord, Jr.: The Technic of Using Vitallium Tubes in Establishing Portacaval Shunts for Portal Hypertension. Ann. Surg., 122: 476–89, 1945.

can connect with systemic veins of the anterior abdominal wall. The third by-pass may result from dilatation of veins at the abdominal sites where the gastrointestinal tract and its appendages become retroperitoneal developmentally, or adherent to the abdominal wall as a result of some pathologic process.

The syndrome of portal bed block, frequently called Banti's syndrome, consists of a variable secondary anemia, leukopenia, thrombocytopenia, splenomegaly and a tendency to severe gastrointestinal hemorrhage which is most frequently associated with ruptured esophageal varices. The liver may be cirrhotic or normal, depending upon the site of the portal bed obstruction. The intrahepatic type is most commonly caused by periportal liver cirrhosis of the Laennec type. The extrahepatic portal block occurs in two ways. In one, fibrous tissue develops secondary to inflammation, trauma, or pressure from within by inflammatory or neoplastic tissue, or the rarer kind seen in young children and due to extension of the obliterative fibrotic process that takes place in the umbilical vein and ductus venosus at birth passing into the portal venous system. The second type of extrahepatic block is a cavernous transformation of the portal vein or its main tributaries, thought possibly due to recanalization of an organized thrombus, or the result of telangiectatic granulation tissue or a congenital anomaly, or an angioma.

The treatment of portal bed block at one time consisted in reducing portal blood flow approximately 40 per cent by splenectomy, or the Talma-Morison procedure of placing omentum in contact with an abraded liver surface in the hope of establishing collateral circu-

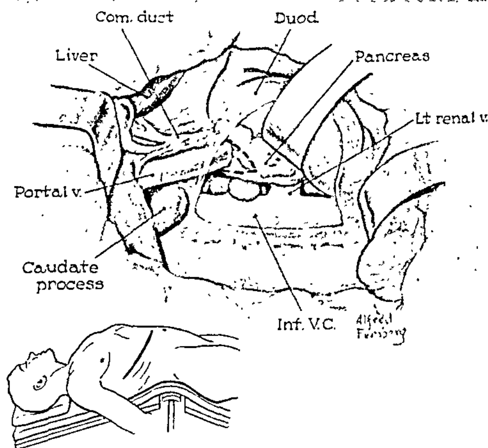


Fig. 442. EXPOSURE FOR PORTACAVAL ANASTOMOSIS.

Patient in the supine position with right side elevated to an angle of 40 to 45 degrees. Thoracoabdominal approach through the resected bed of the ninth rib and its costal cartilage. The first and second portions of the duodenum have been rotated medially. The relation of the portal vein, common bile duct, and caudate process of the liver to one another is outlined. Sometimes the caudate process of the liver is so large as to encroach upon the site of the anastomosis and is therefore resected. The dotted line represents the usual wedge of pancreatic tissue that is resected to prevent angulation and compression of the portal vein when it is shifted into position for the anastomosis. (Blackmore and Voorhees, from Madden: Atlas of Technics in Surgery. In Press. Appleton-Century-Crofts, New York.)

Portal v.

Stump of portal v.

Inf. V.C.

Alfred Feinberg

Fig. 445. COMPLETED END-TO-SIDE PORTACAVAL ANASTOMOSIS.

Emphasizing the obliquity of the shunt and the wedge resection of the adjacent pancreas. (Blackmore and Voorhees, from Madden: Atlas of Technics in Surgery In Press. Appleton-Century-Crofts, New York.)

mesenteric and splenic veins. Decompression can then be accomplished by bridging the gap between the dilated portal vessel and the inferior vena cava by a vein graft, or by dividing the inferior vena cava at the confluence of the iliac veins and anastomosing the proximal cut end to the superior mesenteric vein. This procedure was done on two patients with excellent results. Such a shunt offers certain advantages over the autogenous vein-graft technique: (1) a single anastomosis, (2) a larger anatomic orifice, and (3) a technique useful in children when available donor veins for grafting are small. They found that the elective ligation of the inferior vena cava was, in the absence of pre-existing thrombotic disease, well tolerated, there being no swelling of the lower extremities.

HEPATIC ABSCESS. In the absence of an open wound, pus-forming organisms may reach the liver along various channels, most frequently by the portal and hepatic vessels. In the majority of instances infection is conveyed to the liver by emboli, or by a thrombophlebitis spreading along the portal vein from any part of the area drained by the tributaries of this vessel. Usually the infection begins in the intestinal canal in the ulcerations of dysentery, in appendicitis or in the wounds of rectal

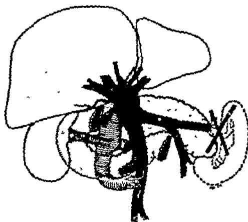


Fig. 446. A NEW TYPE OF PORTAL-TO-SYSTEMIC VENOUS SHUNT FOR PORTAL HYPERTENSION.

An anastomosis between the side of the superior mesenteric vein and the proximal cut end of inferior vena cava is depicted. This type of shunt is used in the management of patients in whom the spleen has been removed (postsplenectomy bleeder) and in whom the periportal vessels preclude dissection in this area. (From Clatworthy, Jr Wall and Watman: Arch. Surg., 71: 588–99, 1955.)

veins at the site of the anastomosis, or turbulence in the vena cava or renal vein in close proximity to the shunt, may spell disaster.

As a result of animal experimentation and observation derived from 350 portacaval shunts in the human being, Blakemore and Voorhees, Jr.,* are convinced that the end-to-side portacaval anastomosis is the most efficient and that the side-to-side portacaval shunt or the splenorenal anastomosis is less efficient.

A right thoracoabdominal incision gives good access to the portal vein and inferior vena cava (Fig. 442). Other important anatomical features of a good portacaval anastomosis recently emphasized by Blakemore and Voorhees as significant steps leading to a better flow of blood are taking a wedge out of the side of the pancreas to lessen possible angulation of the portal vein as it turns down to the anastomosis (Fig. 442), resection of the caudate lobe of the liver if it possibly encroaches on the anastomosis (Fig. 443), and medial placement of the portal vein into the vena cava (Figs. 444, 445).

* Arch. Surg., 74: 978–88, 1957.

Shunt of Inferior Vena Cava to Portal System. The majority of patients with symptoms producing portal hypertension are amenable to a conventional splenorenal or portacaval shunt (Fig. 446). Clatworthy, Wall and Watman** list four sizable groups for whom such established procedures are impossible: (1) the "postsplenectomy bleeder" with cavernomatous changes in the portal vein itself, (2) the patient with pre-existent thrombosis and recanalization of the portal vein and its major tributaries, (3) the person with excessive bleeding at operation from periportal or perisplenic collateral vessels, and (4) the small child in whom the difficulties of obtaining an adequate-sized patent portal-to-systemic venous shunt may be almost insurmountable. In each such case the primary problem is that of demonstrating and dissecting out a portal venous radicle of suitable size. Portal venography may demonstrate in such instances a dilated superior mesenteric drainage vessel or a large "blood lake" at the confluence of the superior

** Arch. Surg., 71: 588–99, 1955.

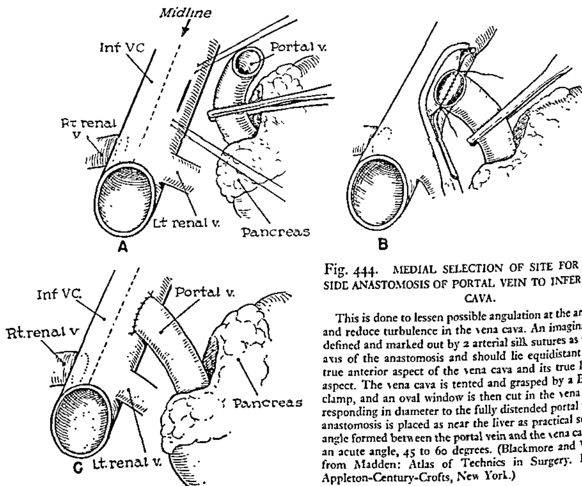


Fig. 444. MEDIAL SELECTION OF SITE FOR END-TO-SIDE ANASTOMOSIS OF PORTAL VEIN TO INFERIOR VENA CAVA.

This is done to lessen possible angulation at the anastomosis and reduce turbulence in the vena cava. An imaginary line is defined and marked out by 2 arterial silk sutures as the future axis of the anastomosis and should lie equidistant from the true anterior aspect of the vena cava and its true left lateral aspect. The vena cava is tented and grasped by a Beck-Potts clamp, and an oval window is then cut in the vena cava corresponding in diameter to the fully distended portal vein. The anastomosis is placed as near the liver as practical so that the angle formed between the portal vein and the vena cava will be an acute angle, 45 to 60 degrees. (Blackmore and Voorhees, from Madden: Atlas of Technics in Surgery. In Press Appleton-Century-Crofts, New York.)

Fig. 445. COMPLETED END-TO-SIDE PORTACAVAL ANASTOMOSIS.
Emphasizing the obliquity of the shunt and the wedge resection of the adjacent pancreas. (Blackmore and Voorhees, from Madden: Atlas of Technics in Surgery. In Press. Appleton-Century-Crofts, New York.)

mesenteric and splenic veins. Decompression can then be accomplished by bridging the gap between the dilated portal vessel and the inferior vena cava by a vein graft, or by dividing the inferior vena cava at the confluence of the iliac veins and anastomosing the proximal cut end to the superior mesenteric vein. This procedure was done on two patients with excellent results. Such a shunt offers certain advantages over the autogenous vein-graft technique: (1) a single anastomosis, (2) a larger anatomic orifice, and (3) a technique useful in children when available donor veins for grafting are small. They found that the elective ligation of the inferior vena cava was, in the absence of pre-existing thrombotic disease, well tolerated, there being no swelling of the lower extremities.

HEPATIC ABSCESS. In the absence of an open wound, pus-forming organisms may reach the liver along various channels, most frequently by the portal and hepatic vessels. In the majority of instances infection is conveyed to the liver by emboli, or by a thrombophlebitis spreading along the portal vein from any part of the area drained by the tributaries of this vessel. Usually the infection begins in the intestinal canal in the ulcerations of dysentery, in appendicitis or in the wounds of rectal

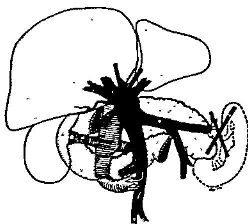


Fig. 446. A NEW TYPE OF PORTAL-TO-SYSTEMIC VENOUS SHUNT FOR PORTAL HYPERTENSION.

An anastomosis between the side of the superior mesenteric vein and the proximal cut end of inferior vena cava is depicted. This type of shunt is used in the management of patients in whom the spleen has been removed (postsplenectomy bleeder) and in whom the periportal vessels preclude dissection in this area. (From Clatworthy, Jr Wall and Watman: Arch. Surg., 71: 588–99, 1955.)

operations. If there is a general pyemia, infective emboli, after traveling through the lungs, find their way to the hepatic artery. A not uncommon infective focus is the lateral sinus, which may become inflamed and thrombosed as a complication of middle ear disease. Long before the pathologic connection between remote foci of suppuration was understood clearly, attention was drawn to the frequent association of intracranial suppuration and liver abscess.

Liver abscesses are multiple or solitary. *Multiple abscesses* generally are of pyemic origin; they are small and are diffusely scattered through the liver, beyond the scope of surgical treatment. The *solitary* or *tropical abscess*, however, is of surgical interest because of the complications to which it may give rise and the form of treatment it demands. The tropical abscess is a manifestation of amebiasis and is associated with acute or chronic dysentery. Abscesses may occur anywhere in the liver structure, but four fifths of them appear in the right lobe. The favorite locations for abscess are the dome and the under surface of the liver. The abscess at first is deep, but, as it increases in size and causes progressive liver destruction and localized or uniform liver enlargement, it tends to make its way to the surface. Upon reaching the surface, an abscess may rupture into a neighboring cavity or viscus. It may burst into the general peritoneal cavity or, if adhesions have been formed, into the stomach, colon or duodenum.

When an abscess erodes through the diaphragm and reaches the pleural cavity, it sets up a diffuse pleurisy. This complication usually is prevented by pleural adhesions between the lung and the diaphragm, in which case the abscess may invade the lung, empty into a bronchus, and be evacuated by expectoration. The pus, if copious, may cause suffocation. If the abscess is located posteriorly, it may penetrate the loose tissue behind the liver and diaphragm and extend along the perinephric tissue toward the lumbar region. It has been known to erode between the ribs, and to make its way forward through the anterior abdominal wall.

Surgical Routes to the Liver. The evacuation of a large hepatic abscess by surgical measures (hepatotomy) is indicated as soon as the presence of pus has been ascertained. The location of the abscess and the direction in which it enlarges most freely determine the route by which it must be evacuated, whether subcostally through the abdominal wall, or through the chest wall. *In no circumstances should a pyogenic hepatic abscess be drained transpleurally*, because of the danger of contaminating the pleural cavity and thereby greatly increasing the mortality rate. Contamination of both the pleural and peritoneal cavities can be obviated by the retroperitoneal operation.

Admirable exposure of the anterior aspect of the liver is obtained by an oblique, subcostal incision immediately below the costal arch, that is, by the *abdominal transperitoneal route* (Fig. 450A). Continuation of the incision allows exposure of the left lobe. When adhesions have formed between the parietal peritoneum and the hepatic serosa, incision may be made directly into the liver substance and the operation be completed in one stage. When no adhesions have formed between the liver and the abdominal wall and when the patient's condition brooks no delay, the suspected area of liver may be walled off carefully and the abscess evacuated through the abdominal incision without contaminating the abdomen. The edges of the abscess cavity then are sutured to the abdominal opening. If the patient's condition permits, the parietal peritoneum may be sutured to the liver about the suspected area, and the suture line be protected by a ring of gauze packing. The incision may be made directly into the liver or be deferred until the general cavity has been walled off from the suspected abscess area.

Postoperatively, antibiotics systemically aid in handling both the pyogenic abscess and possible peritoneal contamination. For amebic abscesses, emetine should be given preoperatively and postoperatively, and antibiotics should be used to ward off secondary contamination by pyogenic organisms.

An approach to the diaphragm by the *thoracic subpleural route* contemplates subperiosteal excision of one or more of the lower ribs in the midaxillary line, at a level above the diaphragm, but below the line of pleural reflection (p. 412). When there are adhesions between the diaphragmatic and hepatic peritoneum, the abscess may be opened at once and drainage established. When no adhesions are present, the margins of the diaphragmatic opening may be sutured to the liver and the suture line protected by gauze packing so that the abscess may be opened.

Echinococcus (Hydatid) Cysts. Hydatid

cysts develop from the ovum of the *Taenia echinococcus* (dog tapeworm), and are found more frequently in the liver than in any other part of the body. Generally, a single cyst occurs. The ovum is carried to the stomach with the food, and its outer envelope is dissolved, setting the embryo free in the intestinal tract. The embryo makes its way through the intestinal mucous membrane into one of the portal radicles. On reaching the liver it develops into a hydatid cyst, which may attain large dimensions, causing the liver to increase greatly in size. When the enlarging cyst invades the subdiaphragmatic region, it compresses the lungs and heart, impeding respiration and causing cardiac distress. During a coughing spell it may rupture into the pleural cavity, but more commonly into one of the bronchi, where the sudden gush of its contents may cause suffocation.

The treatment consists in injection of 2 per cent formalin into the cyst to kill echinococci present, followed by incision and evacuation of its contents. This may be done by the abdominal route and in a one- or two-stage procedure (Figs. 449, 450A). In the one-stage procedure care must be taken to prevent the contents of the cyst from entering the peritoneal cavity, lest the disease be spread.

Contusions and Lacerations of the Liver. The overlying ribs protect the liver from direct violence, but sometimes it is contused and even lacerated seriously. Some injury is attributable, no doubt, to its solidity and fixation, and to the somewhat yielding quality of the lower ribs. The friability of the organ renders it liable to rupture, an accident which is even more likely to occur when the liver size is increased by disease. Sometimes Glisson's capsule and the peritoneum surrounding the liver may remain untorn, and the liver substance suffer severe damage. The more serious injuries cause deep fissures, especially upon the visceral aspect, complicated by free hemorrhage and extravasation of bile into the peritoneal cavity. The blood in the liver is under slight pressure, and

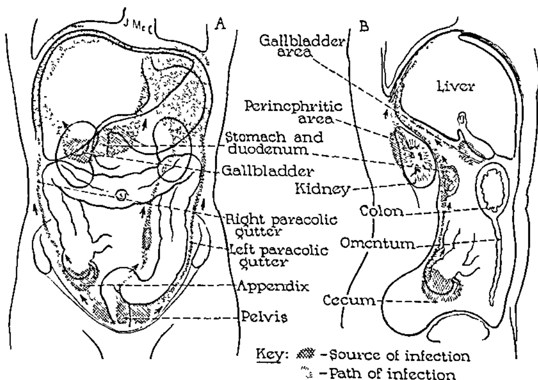


Fig. 447. ETIOLOGY AND PATHS OF INFECTION CAUSING SUBDIAPHRAGMATIC ABSCESS.

Origin in 52 cases: appendicitis, 40 per cent; perforated duodenal ulcer, 17 per cent; from stomach, 9 per cent; pelvic inflammatory disease, 6 per cent; gallbladder disease, 4 per cent; other intra-abdominal inflammations, 24 per cent.

Location of abscess in 52 cases: right suprahepatic posterior space, 69 per cent; right suprahepatic posterior and right subhepatic space, 10 per cent; right suprahepatic anterior space, 4 per cent; left suprahepatic space, 10 per cent; right and left suprahepatic spaces, 4 per cent; perisplenic area, 3 per cent. (From Wellman and Maddock: Univ. Hosp. Bull., Ann. Arbor, 5: 10-12, 1939.)

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Echinococcus (Hydatid) Cysts. Hydatid

stomach below. Because the liver occupies the bulk of this space, and because its peritoneal connections are the key to a correct understanding of the area beneath the diaphragm in which residual abscesses may form, we propose to orient our discussion with reference to the liver rather than to the diaphragm itself, which surmounts the whole area like a cupola.

The abdominal surface of the liver is covered everywhere by peritoneum, except over that portion which lies in direct contact with the diaphragm. It is important to visualize this "bare area," bare of peritoneum, lying almost directly posteriorly—placed against the posterior part of the diaphragm (Fig. 432). The superior and inferior reflections of peritoneum from the liver to the diaphragm which outline the bare area are continued directly laterally as the triangular (lateral) ligaments of the liver. The bulk of the liver is located superior to this composite line of peritoneal reflection; at this line the superior or convex surface of the right and left liver lobes practically begins. The concave surface of the liver lies inferior to this line of reflection. Intraperitoneal subdiaphragmatic collections of fluid, as we interpret them, lie superior to this posteriorly placed hinge of peritoneal reflection, or inferior to it.

On the RIGHT SIDE a *suprahepatic* collection of fluid may be located posteriorly near the peritoneal reflection, or it may form more anteriorly, near the costal margin. These areas we regard as the anterior and posterior divisions of the suprahepatic space. By far the majority of subdiaphragmatic abscesses are suprahepatic and lie in the posteriorly located space (Fig. 447). A fair number simultaneously involve the right subhepatic space, which occupies the area between the concave surface of the right lobe of the liver and the barrier formed by the kidney and transverse colon and mesocolon. A subhepatic collection may be limited to a posteriorly and superiorly placed abscess. It then lies between the inferior peritoneal reflection and the upper pole of the right kidney (Fig. 449), and is designated as an

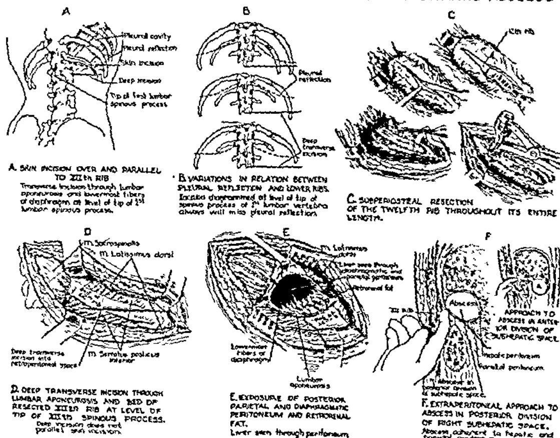
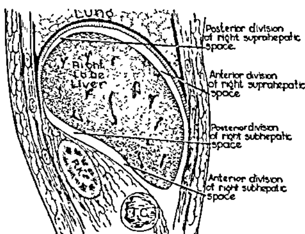
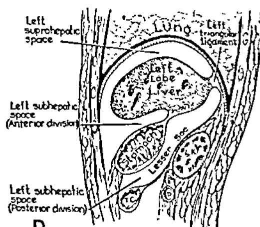
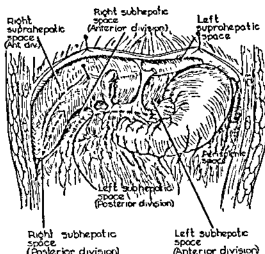


Fig. 449. POSTERIOR EXTRAPERITONEAL APPROACH TO A RIGHT SUBHEPATIC ABSCESS.

(Modified from Nather and Ochsner: Surg., Gynec. & Obst., 37: 665–73, 1923.)







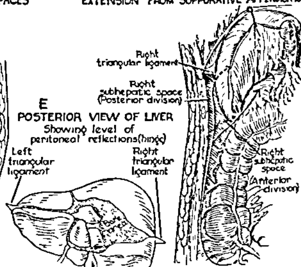


Fig. 448. LOCATIONS OF SUBDIAPHRAGMATIC (SUPRAHEPATIC AND INFRAHEPATIC) ABSCESSES. (Callander.)

careful packing generally is efficient both in checking the hemorrhage and in furnishing the necessary drainage. A penetrating wound of the chest wall below the horizontal level of the fifth rib in the mammary line, if deep enough, may traverse the pleural cavity and diaphragm, and penetrate the liver. Such a wound usually implicates the lower thin edge of the lung in the costodiaphragmatic pleural recess. Sharp ends of fractured ribs may be driven through the diaphragm into the liver.

Suprahepatic and Infrahepatic Divisions of the Subdiaphragmatic Space, and their Relation to Subdiaphragmatic Abscess. In general, the subdiaphragmatic (subphrenic) space is extensive and is not uncommonly involved with an abscess as a complication of an intra-abdominal inflammation (Fig. 448). Failure of a patient to improve satisfactorily after any abdominal infection should make the surgeon suspect this area, which is well hidden up under the ribs, and to search for every evidence of its involvement.

The subdiaphragmatic space is closed or hooded above by the diaphragm, and is partially barred from the rest of the abdominal cavity below by the transverse mesocolon and transverse colon. In the presence of infection these structures and the great omentum adhere firmly to the anterior abdominal wall and limit the downward extension of inflammatory products. On the right the large right lobe of the liver is interposed between these two natural boundaries. The falciform ligament, sagittally placed, divides the area into right and left segments. On the left side are the small left lobe of the liver above and the frontally disposed gastrohepatic (lesser) omentum and

phragm is difficult because of inflammatory reaction from the underlying abscess, so that this approach is not often selected. Transdiaphragmatic *transpleural* drainage through rib resection and suture of the opposed costal and diaphragmatic layers of pleura in one or two stages is a procedure used much too frequently. The walling-off practice often does not protect the rest of the pleural cavity.

TRANSABDOMINAL *transperitoneal* drainage which permits contamination of uninvolved areas of peritoneum is a poor procedure, satisfactory only when the inflammation has walled off normally open areas. Transabdominal *extraperitoneal* drainage is the method best adapted to the evacuation of all varieties of subdiaphragmatic abscess, and the approach is anterior or posterior according to the location of the infected area.

Abscesses located in the right and left suprahepatic spaces, and those situated in the anterior division of the left subhepatic area, can be drained extraperitoneally through the anterior abdominal wall (Fig. 450A). An incision just below, and parallel to, either costal margin is developed through the abdominal musculature and transversalis fascia down to the anterior parietal peritoneum. The peritoneum is separated from the under surface of the diaphragm by blunt dissection until the abscess cavity is reached. The cavity is opened extraperitoneally through the abscess wall, which is intimately adherent to the mobilized diaphragmatic peritoneum.

The posterior extraperitoneal approach devised by Nather and Ochsner (Fig. 449) should be used in dealing with abscesses in the anterior or posterior division of the right subhepatic area or with abscess in the right or left extraperitoneal spaces. The posterior part of the suprahepatic space can be reached through this incision. The principle of this, as well as of the anterior approach, is that the peritoneum on the diaphragm can be dissected bluntly toward the dome until the abscess cavity is reached. The abscess can be opened directly, since its wall is adherent to the mobilized diaphragmatic peritoneum.

RIGHT AND LEFT HEPATIC LOBECTOMIES. Brunschwig* has long been interested in this subject as a part of his expansion of the surgical attack upon neoplasms. This has been facilitated by modern supportive treatment, including the use of multiple transfusions to replace blood lost at operation. In resecting large segments of liver, the principle of compression by various means—manual, mass mattress sutures and numerous small compression sutures applied proximal to the line of transection—is a general and long-recognized procedure. Recently Goldsmith and Woodburne,† from an excellent study of surgical anatomy pertaining to liver resection, recommended the planes of section, shown in Figure 450B.

The extent of some hepatic lobectomies is remarkable (Fig. 451). Recent attempts to control bleeding during these procedures include temporary occlusion of the aorta and portal and hepatic veins.

EXTRAHEPATIC BILIARY PASSAGES

The extrahepatic bile tract consists of the hepatic or excretory duct of the liver; the gallbladder, a reservoir in which bile accumulates; the cystic duct, which is the continuation of the gallbladder; and the common duct, which is the union of the hepatic and cystic ducts. With these structures in the hepatic pedicle, or hepatoduodenal ligament, are the portal vein and branches of the hepatic artery. These elements are disposed in two layers—the ventral, containing the bile ducts and the hepatic artery, and the dorsal, containing the portal vein (Fig. 424).

The anatomy of the bile passages and the vessels intimately related to them clarifies the rationale of operations performed for the removal of gallstones, and for the treatment of the various inflammatory complications which they incur.

HEPATIC DUCT. The hepatic duct is formed in the depth of the transverse fissure of the liver by the union of the right and left hepatic ducts. The resulting trunk runs downward, backward and mesially in the gastrohepatic ligament (lesser omentum). The length of the duct averages about 4 cm., but may vary considerably, depending upon the level at which it is joined by the cystic duct.

At the liver hilus the duct crosses the portal vein and the branches of the hepatic artery. As it leaves the hilus it lies over the anterolateral aspect of the portal vein and maintains that position to its termination. The hepatic duct is related to the hepatic artery proper, which sometimes runs closely along its left margin,

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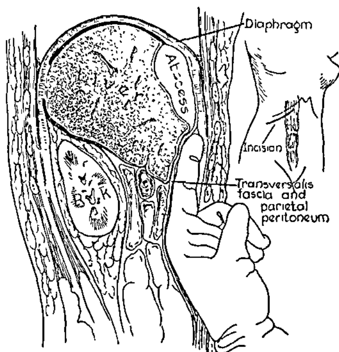


Fig. 450A. ANTERIOR EXTRAPERITONEAL APPROACH TO A SUBDIAPHRAGMATIC (SUPRAHEPATIC) ANTERIOR ABSCESS.

Blunt dissection is outside the transversalis fascia and parietal peritoneum until the abscess is reached (After Clairmong, Ochsner and DeBakey: Internat. Abst. Surg., 66: 426–38, 1938.)

abscess in the posterior division of the subhepatic space. The reason for the frequency of the more posteriorly situated subhepatic and suprahepatic abscess formations is that the exudate from suppurative appendicitis naturally gravitates superiorly along the paracolic gutter, impinges against the right triangular lateral ligament of the liver, and is guided to a posteriorly placed subhepatic position. Residual infection from a ruptured gallbladder or duodenal ulcer more readily gravitates into the anterior area of the subhepatic space.

An intrahepatic infection, posteriorly located, may erode the liver substance in the area devoid of peritoneum and form an abscess there between the liver and the diaphragm in the *right extraperitoneal space.*

On the LEFT of the falciform ligament lies the small left lobe of the liver with its superior convex and inferior concave surfaces. The left triangular ligament along the posterior margin of the lobe hinges the two areas. An abscess located superior to this line of peritoneal reflection is a *left suprahepatic abscess.* Because of the small size of the left lobe of the liver, an abscess here is rare and, of necessity, small. The frontally disposed stomach and gastrohepatic (lesser) omentum naturally subdivide the left *subhepatic area* into anterior and posterior divisions. The posterior of these areas is the lesser peritoneal sac. Residual abscess in the lesser sac may occur after rupture of a posteriorly located gastric ulcer. The anterior area of the left subhepatic space lies between the lesser omentum and the stomach and the anterior abdominal wall. It is limited inferiorly by the ready adhesion of the transverse colon and great omentum against the anterior abdominal wall, which occurs with contiguous infection. Rupture of an anteriorly situated gastric ulcer, or of the gallbladder in which infected contacts spread to the left, places a subhepatic abscess in this location.

A *left extraperitoneal subdiaphragmatic abscess* may form about the upper pole of the left kidney, extend upward, and strip the peritoneum off the diaphragm. The cause of this may be a high perinephric and, therefore, extraperitoneal abscess, or perforation of a carcinoma of the abdominal esophagus in its posterior and, therefore, extraperitoneal area.

PATHS OF APPROACH TO SUBDIAPHRAGMATIC ABSCESS. *The treatment of subdiaphragmatic abscess is accomplished by incision and drainage so that uninvolved portions of pleural and peritoneal cavities are not contaminated.* This basic surgical principle is often disregarded. The paths of approach are transdiaphragmatic and transabdominal, and each variety of approach may be transserous or extraserous.

The TRANSDIAPHRAGMATIC *extrapleural* approach is accomplished through rib resection below the costodiaphragmatic pleural reflection, or through rib resection and upward mobilization of the unopened pleural reflection. Upward mobilization of the pleura on the dia-

phragm is difficult because of inflammatory reaction from the underlying abscess, so that this approach is not often selected. Transdiaphragmatic *transpleural* drainage through rib resection and suture of the opposed costal and diaphragmatic layers of pleura in one or two stages is a procedure used much too frequently. The walling-off practice often does not protect the rest of the pleural cavity.

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Right hepatic vein
Inferior vena cava
Middle hepatic vein
Left hepatic vein
Left triangular ligament
Falciform ligament
Right branch of portal vein:
Left branch of portal vein:
posterior segmental branch
transverse portion
umbilical portion
anterior segmental branch
L₁
L
R

Fig. 450B. PLANES FOR RESECTION OF LIVER LOBES.

The recommended surgical planes of the liver in relation to the portal and hepatic veins. *R* Indicates the plane of preference for a right lobectomy; *L* for a left lobectomy; L_1 for a left lateral segmental resection. (From Goldsmith and Woodburne: Surg., Gynec. & Obst., 105: 310–18, 1957.)

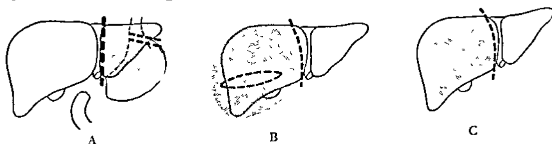


Fig. 451. EXTENT OF HEPATIC LOBECTOMIES.

A, Cancer of stomach. Patient well for 17 years. Adherent to under surface of left lobe. Left lobectomy and subtotal gastrectomy (en masse). *B*, Massive angioma. Two previous attempts at excision. Right lobectomy and excision of abdominal wall. Patient well for 4 years, 2 months. She had radical hysterectomy and pelvic node excision for cancer of the cervix 3 years after right hepatic lobectomy. *C*, Multiple metastases from carcinoma of colon. Patient died of carcinomatosis one month after total right hepatic lobectomy. (From Brunschwig: Cancer, 8: 1226–33, 1955.)

but usually lies some distance from it, especially when the finger introduced into the epiploic foramen draws the lesser omentum forward. From the right branch of the hepatic artery the cystic artery runs dorsal to the hepatic duct, to ramify over the anterior surface of the neck of the gallbladder.

GALLBLADDER. The gallbladder, a thin-walled, pear-shaped sac about 8 to 10 cm. long with a capacity of about 50 cc., lies in a fossa of the inferior surface of the liver which separates the right lobe from the quadrate lobe (Figs. 424, 434). Loose connective tissue and the peritoneum reflected from its sides attach the gallbladder to the liver.

The large bulbous extremity, or *fundus*, is partly covered with peritoneum, and is directed downward, forward and to the left. It occupies the cystic notch in the margin of the liver and exceeds it for a distance of 1 cm. or more.

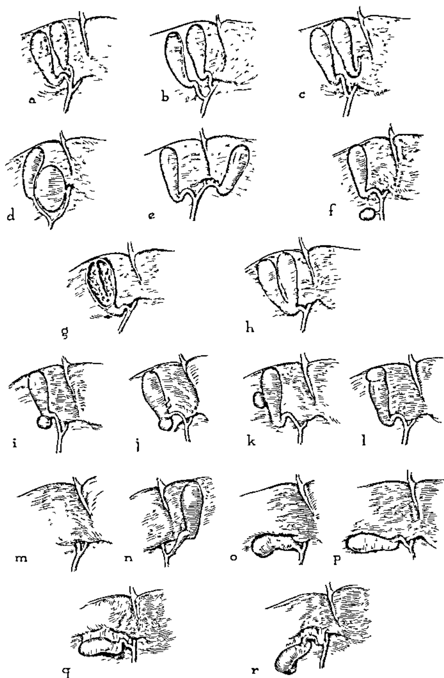


Fig. 452. CONGENITAL ANOMALIES OF THE GALLBLADDER.

a to *f*, Types of double gallbladder, showing the position of the accessory organ and relationship of the cystic duct. *a*, Regular and accessory gallbladders lodged in a fossa of normal position and possessing a common cystic duct. *b*, A pattern differing from the preceding in the occurrence of separate cystic ducts. *c*, Termination of one of the cystic ducts in the liver. *d*, An accessory gallbladder, with a cystic duct terminating in the common hepatic duct. *e*, An accessory *vesica* situated beneath the left lobe of the liver. *f*, An instance of doubling, in which the accessory gallbladder, situated in the lesser omentum, emptied into the common bile duct.

g and *h*, Forms of bilobed gallbladder. *g*, Partially separated by an internal septum *h*, Paired through the fundus and body, but joined at the neck to form a single cystic duct.

i to *l*, Types of congenital diverticula. *i*, *j*, Diverticulum at the neck of the gallbladder. *k*, Cul-de-sac from the body of the organ. *l*, Similar expansion at the fundus.

m to *p*, Abnormality in position of the gallbladder. *m*, Lodgment within the substance of the liver. *n*, Placement under the left hepatic lobe. *o*, *p*, Posterior situation under the right lobe.

q and *r*, Floating gallbladders suspended by a mesenteriole. *q*, Peritoneal fold passing the entire length of the gallbladder and cystic duct. *r*, Peritoneal reflection supporting only the cystic duct, the gallbladder thus hanging free and being movable. (Redrawn from Gross: Arch. Surg., 32: 131–62, 1936.)

When the gallbladder is full, the fundus comes into contact with the anterior abdominal wall opposite the ninth costal cartilage, where it can be marked out in the angle between the right rectus muscle and the costal margin.

The *body* of the gallbladder is united to the inferior surface of the liver. Normally there is no peritoneum between the body of the gallbladder and the liver fossa, but occasionally the gallbladder is attached so loosely as to be freely mobile and is suspended from the liver as by a mesentery. The degree of difficulty experienced in isolating the gallbladder and separating it from its bed depends somewhat upon the degree to which the peritoneum binds it to the liver. Small vessels and even small biliary channels may connect the two. Hemorrhage from these vessels usually is slight.

The body is continued into the tapering extremity or *neck* of the gallbladder, which presents a sinuous or S-shaped curve downward to reach a termination in the cystic duct. It occupies the deepest part of the cystic fossa, and lies in the uppermost free portion of the lesser omentum. It contains the remainder of the embryonic spiral valve (of Heister), which makes catheterization from above difficult. Between the body and the cystic duct is a forward bulging which is the *ampulla*.

Anomalies of the gallbladder are rare in man, but important when they do occur.* A comprehensive review of the literature by Gross recorded 148 cases. The various forms assumed by the anomalous *vesica fellea* may be briefly catalogued and described as follows (Fig. 452): double (two separate cavities and independent cystic ducts); bilobed (bifid or partially divided gallbladder, draining into a single cystic duct); diverticular (a blind sac or branching from the main vesical space, which may be found at any point between the fundus and the neck); floating (suspended by a mesenteriole, which may pass along the entire length of the gallbladder and cystic duct or, in being limited to the duct, allow the *vesica* to hang free); malposition (intrahepatic, left-sided or retrodisplaced).

The *mucosa* is so rich in mucus-secreting glands that, when the ampulla or cystic duct is obstructed by an impacted calculus, the gallbladder may dilate and form a *mucocele*, often referred to as containing *white bile*. As this obstruction offers no obstacle to the free passage of bile from the liver into the duodenum, the inflammation of the gallbladder sometimes associated with it need not cause jaundice.

The relations of the gallbladder to the duodenum and transverse colon explain their not infrequent adhesion, and the occasional rupture and passage of pus and gallstones from the one to the other (Fig. 453). They also explain the rationale of surgical anastomosis between the gallbladder and duodenum for common duct obstruction due to carcinoma of the head of the pancreas.

The gallbladder undergoes great changes in size under normal conditions, but in the pathologic state its size varies from enormous distention to contraction into a fibrous mass. When it becomes distended, it enlarges in a down-

* Here Dr. Boyden's classical article on the embryology and comparative anatomy of aberrant biliary vesicles will be found highly instructive. (Am. J. Anat., 38: 177–231, 1926.)

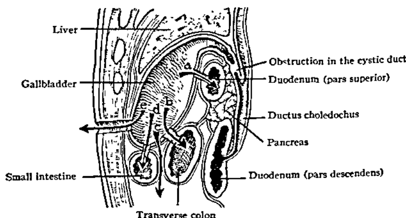


Fig. 453. PARAMEDIAN SAGITTAL DIAGRAM SHOWING PATHS OF SPONTANEOUS RUPTURE OF AN EMPYEMA OF THE GALLBLADDER.

a, Rupture into the duodenum; *b*, erosion into transverse colon; *c*, rupture into the general peritoneal cavity; *d*, rupture into the small intestine; *e*, erosion through the abdominal wall.

ward and medial direction, forming a readily palpable, movable tumor which may be mistaken for a floating kidney. In obstruction in the terminal portion of the biliary apparatus from a noninflammatory lesion, such as a cancer of the head of the pancreas or of the termination of the common duct, the obstruction is likely to be complete; and, since the gallbladder wall is normal, the gallbladder may *become distended. Obstruction caused by a* calculus usually is not complete, and also is generally associated with inflammation of the bile passages (cholangitis) and the gallbladder wall. As a result, the gallbladder does not distend. This is Courvoisier's Law. When there is jaundice and a distended gallbladder, the diagnosis is almost 100 per cent for carcinoma of the head of the pancreas. However, in only 50 per cent of the cases of carcinoma of the head of the pancreas is the gallbladder found distended.

Cystic Duct. The cystic duct, continuing the neck of the gallbladder, is about 4 cm. long, but is folded upon itself so that its union with the hepatic duct occurs close to the neck of the gallbladder. It usually runs some distance beside the hepatic duct before opening into it. However, variations are common (Fig. 436). The redundant lining is arranged into a series of folds which produce the spiral *valve of Heister*. This valve obstructs the passage of an instrument, save when the duct is dilated greatly by the passage of stones or by obstruction of the common duct. The folds may offer sufficient obstruction to cause calculi to become impacted. The cystic artery accompanies the duct, usually running on the left side.

Common Bile Duct. The common bile duct, although conveniently regarded as the *union of the cystic and hepatic ducts, really is* the direct continuation of the hepatic duct (Figs. 424, 454). It is about 9 cm. long, and passes downward in the lesser omentum (supraduodenal portion), behind the duodenum (retroduodenal portion) in a groove of, or behind, the pancreas (pancreatic portion), and obliquely into the descending duodenum (intraduodenal portion). Departures from the so-called typical patterns are frequent; they affect the manner of formation of the common bile duct, the number and relations of extrahilar (accessory) hepatic ducts and the point of emergence of the latter from the hepatic parenchyma (Figs. 455 to 458).

The *supraduodenal*, or *first*, *part of the duct* is about 3.5 cm. long, but may be shortened by the opening of the cystic duct into the hepatic duct close to the superior margin of the duodenum. It descends along the right margin of the lesser omentum to the right of the hepatic

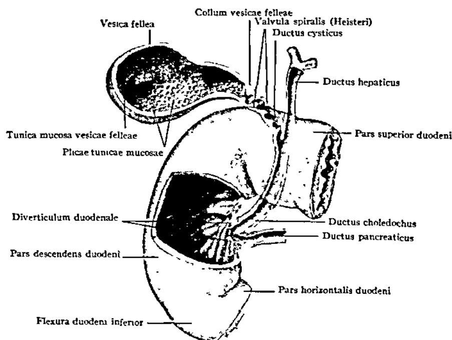


Fig. 454. GALLBLADDER AND BILE DUCTS AND THEIR RELATIONS WITH THE DUODENUM.

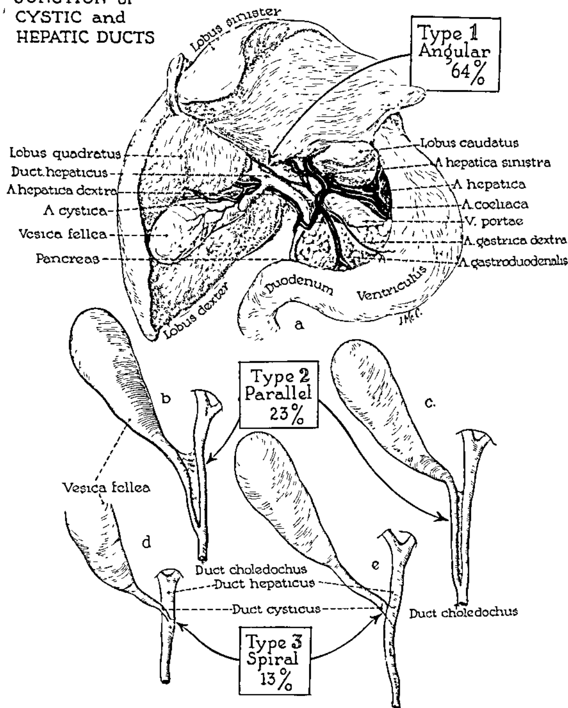


Fig. 455. TYPES OF JUNCTION OF THE CYSTIC AND HEPATIC DUCTS.

a, An acute-angled junction occurs in almost two thirds of the cases. *b*, *c*, The short parallel type is next in frequency of occurrence. *d*, *e*, Posterior junction following a spiralling course is the least frequent of the three. (From Johnston and Anson: Surg., Gynec. & Obst., 94: 669–86, 1952.)

artery, anterior to the portal vein. The lymph nodes related to the common duct at its beginning and termination may become enlarged in infections of the bile passages and in malignancy of the stomach and pancreas, and be mistaken for impacted gallstones. Downward pressure on the duodenum and division of the hepatocolic ligament, if it is present, expose the supraduodenal and retroduodenal parts of the duct. The index finger of the left hand is passed into the epiploic foramen, and the supraduodenal part of the duct is palpated between the left forefinger and thumb. A stone may be milked from more distal locations in the

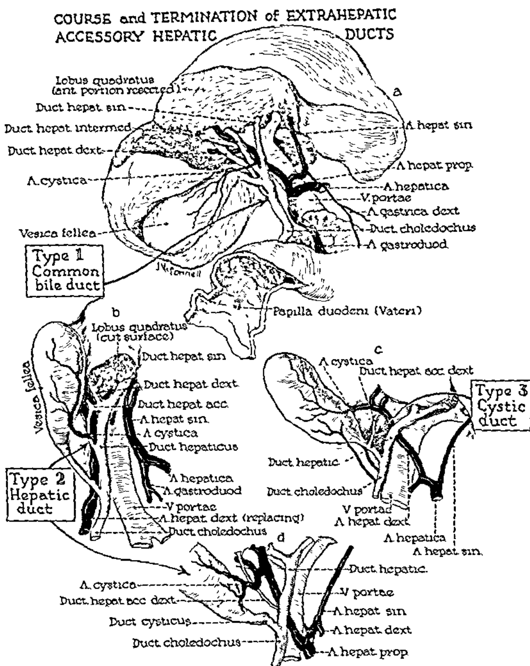


Fig. 456. VARIATIONS IN THE COURSE AND TERMINATION OF EXTRAHILAR ACCESSORY HEPATIC DUCTS.

Examples encountered in an examination of 35 specimens. *a*, Specimen with no common hepatic duct; owing to the low insertion of a large right hepatic duct *into the common bile duct (i.e., below the cystic duct junction), a common hepatic* duct does not exist. The relation of the cystic artery to the hepatic ducts is also unusual. *b*, Heretofore undescribed type of accessory hepatic duct from the right hepatic duct which coursed around the right hepatic artery and rejoined the common hepatic duct (5 specimens). *Also shown is the relation of an anomalous right hepatic artery to the bile ducts* and portal vein. *c*, Accessory hepatic duct joining the cystic duct (4 specimens). *d*, Accessory duct joining the common hepatic duct. (From Johnston and Anson: Surg., Gynec. & Obst., 94: 669–86, 1952.)

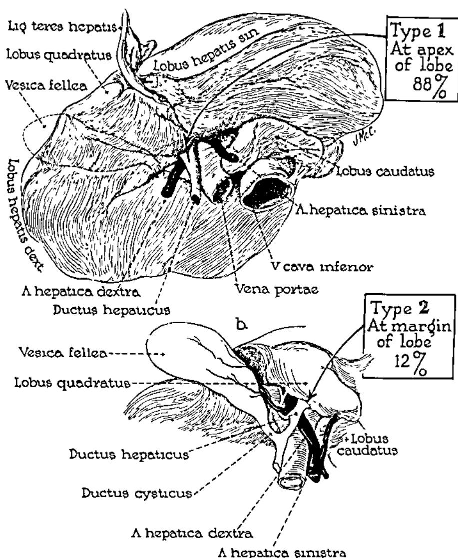


Fig. 457. PRINCIPAL POINTS OF EMERGENCE OF THE HEPATIC DUCTS IN RELATION TO THE QUADRATE LOBE. Types encountered in 33 specimens. (From Johnston and Anson: Surg., Gynec. & Obst., 94: 669–86, 1952.)

duct. If a calculus is present in the termination of the common duct, the proximal parts of the duct, including the supraduodenal portion, are dilated, a condition which admits of surgical exploration upward into the hepatic ducts and downward into the duodenum through an incision in the supraduodenal portion.

The *retroduodenal*, or *second*, *part of the duct* descends behind the first part of the duodenum anterior to the vena cava and to the right of the portal vein (Figs. 459, 460). There are 1 or 2 cm. of the upper duodenal wall to which the duct does not adhere, and which may be exposed by incising the anterior layer of the lesser omentum at the upper margin of the duodenum and drawing the duodenum downward. To examine the second part of the duct, the forefinger is placed in the epiploic foramen and the thumb on the anterolateral aspect of the first part of the duodenum. Between the two fingers the presence of impacted stones can be recognized. It sometimes is necessary to mobilize the descending duodenum to expose the second part of the bile duct, but usually stones can be manipulated upward into the supraduodenal part or downward into the duodenum.

The *pancreatic*, or *third*, *part of the duct* begins at the upper margin of the head of the pancreas, the posterior surface of which it

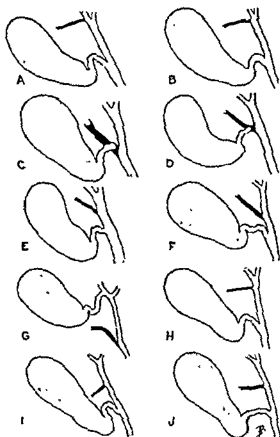


Fig. 458. ACCESSORY EXTRAHEPATIC DUCTS. VARIATIONS ENCOUNTERED IN 100 CADAVERS.

A, Accessory duct empties into right hepatic duct in transverse fissure (*porta hepatis*). Distance between accessory duct and the junction between the cystic duct with the common hepatic duct is 3.5 cm. *B*, Essentially as in *A*. The distance between the cystic duct and accessory duct is 2.1 cm. *C*, Cystic duct empties into the accessory duct close to its junction with the common hepatic duct. Accessory duct approximates the diameter of the common hepatic duct. Distance between accessory duct junction with common hepatic duct and junction of right and left hepatic duct is 2.7 cm. *D*, Characteristics essentially the same as C. Distance between junction of right and left hepatic ducts with the junction of accessory duct with common hepatic duct is 1.2 cm. *E*, *I*, *F*, This group is essentially the same in that the accessory duct empties into the common hepatic duct midway between the junction of right and left hepatic ducts and the junction of cystic duct with common hepatic duct. Length of common hepatic duct in *E* and *I* is 3 cm., and in *J* is 2.2 cm. *F*, Accessory hepatic duct empties simultaneously into common hepatic duct with cystic duct. Distance of accessory duct junction from beginning of common hepatic duct is 3.5 cm. Diameters of accessory and common hepatic ducts are the same. *G*, Cystic duct empties into right hepatic duct 1 cm. from hilum of liver. Junction of right and left hepatic ducts approximately 2 cm. from hilum of liver. Accessory hepatic duct empties into common bile duct 2.5 cm. from junction of right and left hepatic ducts and 3.5 cm. from cystic duct junction. Diameter of accessory duct same as common bile duct. *H*, Accessory duct empties into the common hepatic duct just distal to beginning of common hepatic duct. Distance between accessory duct and cystic duct junction with common hepatic ducts is 2.2 cm. Accessory duct lies under the surface of the liver. (From Lichtenstein and Nicosia: Ann. Surg., *141*: 120-24, 1955.)

either grooves or tunnels. This part passes downward and terminates by piercing the *posteromesial* aspect of the descending duodenum at about its middle. It is separated from the inferior vena cava by connective tissue alone or by a thin layer of pancreas. It has no direct relationship with the portal vein, which approaches it obliquely from below and from the left. On its left side the duct is accompanied by the gastroduodenal artery, which, a variable distance down its course, gives off the superior pancreaticoduodenal trunk (p. 477). This trunk crosses the common duct either anteriorly or posteriorly. Its presence and its interlacing branches to the duct explain the hemorrhage which occurs in exposure of the third portion of the duct. Hemorrhage also may be caused by injury to a vein issuing from the posterior aspect of the head of the pancreas and running upward along the mesial aspect of the bile duct to join the portal vein.

The common duct begins its *intraduodenal portion* where it enters the wall of the duodenum obliquely and is joined on the left by the pancreatic duct. The short common reservoir formed by the two ducts partly within the duodenal wall is the *ampulla of Vater*. The ampulla becomes constricted and opens into the duodenum on the summit of the *duodenal papilla*. The opening is so small that gallstones that have passed the cystic and common ducts often become impacted. When this occurs, pancreatic as well as bile secretion may be prevented from entering the duodenum unless there is a communication between the main and accessory pancreatic ducts. This condition and spasm of the sphincter (of Oddi) about the duodenal opening favor reflux of bile into the pancreatic duct with consequent pancreatitis. The common bile duct sometimes narrows a little before opening into the ampulla of Vater and causes impaction of stones. In this case the pancreas is not so likely to be affected. Direct access to a stone impacted in the ampulla of Vater is gained by the transduodenal route (p. 484).

MODES OF TERMINATION OF THE BILE AND PANCREATIC DUCTS. There is considerable variation in the modes of termination of the pan-

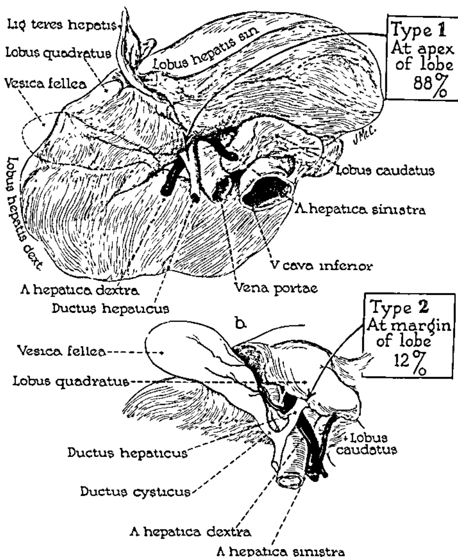


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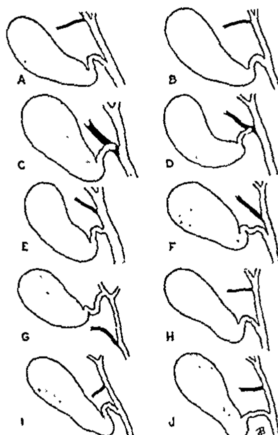


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MODES OF TERMINATION OF THE BILE AND PANCREATIC DUCTS. There is considerable variation in the modes of termination of the pan-

creatic and bile ducts (Fig. 461). Normally there is an ampulla, common to both ducts, opening on the duodenal mucosa on the summit of the duodenal papilla. The two ducts may open independently into the duodenum, each on the summit of a small papilla or in the depth of a slight depression, in which case a stone impacted in the terminal common duct will not cause pancreatic obstruction. The common duct may open at the papilla and the pancreatic duct unite with the common duct at a higher level.

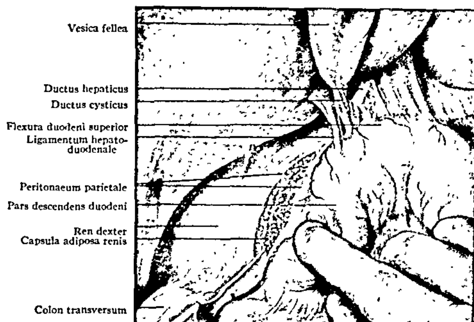


Fig. 459. SURGICAL MOBILIZATION OF THE DESCENDING PART OF THE DUODENUM (KOCHER PROCEDURE).

Mobilizing this part of the duodenum offers a direct approach to the retroduodenal and pancreatic divisions of the common duct; this is accomplished by incising the parietal peritoneum along the descending duodenum, allowing medial retraction. This maneuver also facilitates pyloroplasty.

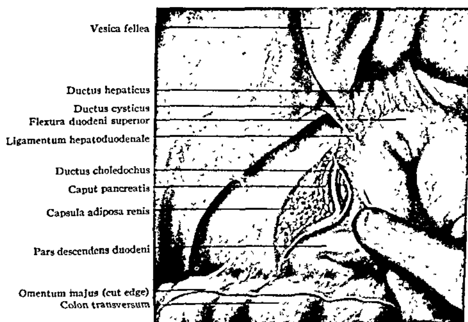


Fig. 460. SURGICAL MOBILIZATION OF THE DESCENDING DUODENUM (COMPLETED).

The common duct is exposed where it grooves the head of the pancreas; this maneuver renders the intrapancreatic portion of the common duct accessible for the removal of calculi or in dealing with stricture of the duct. It also facilitates pyloroplasty.

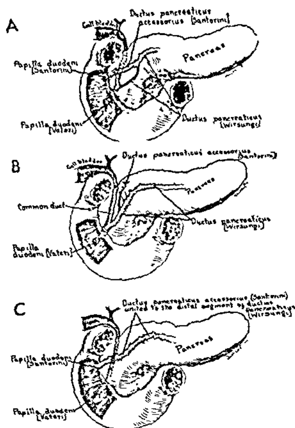


Fig. 461. VARIATIONS IN THE PANCREATIC DUCT SYSTEM.

A, A large accessory pancreatic duct (of Santorini) carries most of the secretion of the pancreas. *B*, A rudimentary accessory duct which, having no connection with the duodenum, empties into the main pancreatic duct (of Wirsung). *C*, An accessory pancreatic duct unites with the distal segment of the main duct, the proximal segment of the latter being absent.

EMPTYING OF THE GALLBLADDER. By discovering a food that would consistently empty the animal gallbladder, and by combining the Graham and Cole method of cholecystography with a method of computing volumes from x-ray shadows, Boyden and his colleagues established the behavior of the human gallbladder in response to a standard meal. In associated studies these methods were used to study the factors governing the process of emptying in both health and disease.

Roentgenograms of the human gallbladder, taken at frequent intervals after the ingestion of food, demonstrate that in man this organ discharges the bulk of its contents into the duodenum during the first part of a meal (Fig. 462). Its primary function is, therefore, the one historically attributed to it, namely, the storage and concentration of those constituents of the bile which are needed for digestion. After its discharge into the duodenum, part of the bile is resorbed by the intestine to act as a cholagogue in accelerating the flow of bile from the liver.

The gallbladder expels its contents by the force of its own musculature; its relatively slow contraction (that is, as compared with the urinary bladder) subserves the purpose of providing a sustained flow of bile during the initial phases of digestion. Among the foods which cause contraction of the gallbladder, egg yolk is preeminent.

Before a meal the gallbladder is not quiescent, but is either slowly filling or contracting. Some of these spontaneous contractions are almost as strong as those induced by the ingestion of food. When emptying of the human gallbladder takes place (as after the "Boyden meal" of egg yolk and milk), action is intermittent (Fig. 463), consisting of one to five phases of contraction, depending somewhat on the size of the gallbladder itself. The time required to empty the gallbladder is variable, ranging from sixteen minutes to four and one-half hours. Terminally, emptying is virtually complete; in no case was the lowest residual volume over 4.5 cc.; in nineteen out of twenty-four cases it was less than 2.25 cc., and in six cases it was 0.5 cc. or less. The first phase of contraction is divided into three parts: (1) the so-called initial response—of approximately two minutes' duration—perhaps merely a change in tonus; (2) the two-minute pause, characterized by a relaxation of the gallbladder that accompanies an initial increase in tonus of the sphincter of Oddi; and (3) the principal period of discharge, which empties two thirds to three fourths of the contents of the gallbladder in the first forty minutes after the meal.

Certain other fatty foods, such as milk and cream, although causing as great a first discharge as egg yolk, induce no subsequent phase of contraction (Fig. 463). From this observation it is inferred that the gallbladder is a trigger mechanism which is set off equally well by any of a large number of appropriate foods, but that subsequent phases and complete emptying depend on a food which is retained in the stomach sufficiently long and is such as to induce repeated phases of contraction by successive spurts of chyme.

These observations led to subsequent study

Fig. 462. ASSEMBLY DRAWINGS SHOWING TRACINGS OF SUCCESSIVE CHOLECYSTOGRAMS.

L 1, 2, 3, Transverse processes of lumbar vertebrae. Heavy outside line represents roentgenogram of gallbladder before meal of egg yolk and cream. Subjects, B. J. Anson and H. M. Teel. Drawings, life size. (From Boyden: Anat. Rec., 33: *201–55, 1926.*)

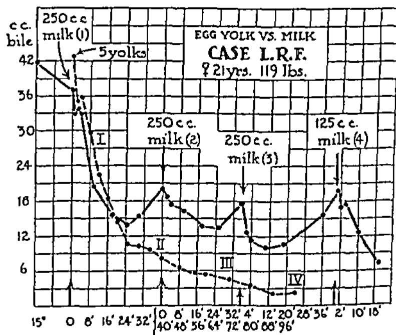


Fig. 463. CONTRACTION CURVES FROM THE SAME PERSON, TAKEN SEVERAL MONTHS APART.

The first series (after yolk and cream) resulted in 4 successive phases of contraction, the first of which is the most effective. The second series (after 4 successive glasses of milk) shows that milk causes only one phase of contraction, and suggests that the phases of contraction after egg yolk are due to repeated spurts of yolk-laden chyme from the stomach. Ordinates, cubic centimeters of bile in the body and fundus of the gallbladder. Abscissas, minutes after ingestion of food. (From Boyden: Anat. Rec., 11: 147-84, 1928.)

of the basic problem, namely, the nature of the mechanism which regulates the flow of bile in man. After Ivy and Oldberg's demonstration of "a hormone mechanism for gallbladder contraction and evacuation,"* the problem became one of whether the human biliary duct system is regulated primarily by cholecystokinin or by the automatic nervous system, or by both. In 1934 Boyden and Rigler** showed that induction currents strong enough to cause colicky pain when applied to the stomach and duodenum by modified Rehfuss tubes failed to stop the emptying of the gallbladder. The human mechanism thus differs markedly from that of a laboratory animal in which induction currents applied anywhere along the gut of an intact animal inhibits evacuation of bile (Birch and Boyden).‡ Recently Johnson§ showed that, after double vagotomy, the evacuation of the gallbladder—which had been accelerated in ulcer patients by the faster initial passage of food into the duodenum—resumes its normal rate, but the gallbladder increases in size. One concludes, therefore, that in man, as contrasted with laboratory animals, the mechanism of emptying is primarily hormonal, and that the nervous system is responsible only for tonus.

Further light has been thrown on this mechanism by recent studies comparing the reaction of the sphincter and gallbladder to magnesium sulfate and to egg yolk.‖ When magnesium sulfate is introduced into the duodenum of cholecystectomized patients, and the resistance of the sphincter is recorded by a manometer attached to a T-tube in the common duct, the pressure increases initially, then decreases over an average period of seventeen minutes, then increases again (Fig. 464). When magnesium sulfate is introduced into the duodenum of normal subjects, the gallbladder volume shows initial fluctuation, then diminishes steadily over an average period of thirty minutes, and then increases again. In other

* Am. J. Physiol., 84: 599, 1928.
** Anat. Rec., 59: 427–45, 1934.
‡ Am. J. Physiol., 92: 301–16, 1930.
§ Johnson: Surgery, 32: 591–601, 1952.
‖ Bergh and Layne: Am. J. Digest. Dis., 9: 162–5, 1942.

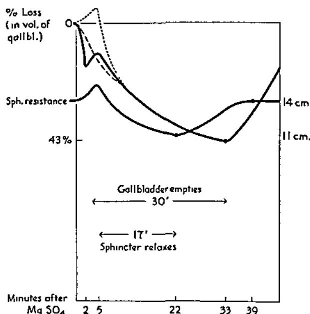


Fig. 464. GRAPH ILLUSTRATING THE SEQUENCE OF EVENTS AFTER DUODENAL ADMINISTRATION OF MAGNESIUM SULFATE.

Upper lines, curves recording average decrease of 43 per cent in volume of 10 gallbladders. Dotted line, 3 cases in which the gallbladder first reacted by relaxing, thereby appearing to increase its volume temporarily; dash line, 3 cases in which the gallbladder reacted by contracting only; solid line, 3 cases in which it first contracted (for 2 minutes), then relaxed (for an average of 3 minutes), then entered its main phase of contraction. Lower solid line, curve recording mean changes in resistance of sphincter in 12 patients. In all 12, the sphincter reacted first by increasing its resistance (from an average manometer reading of 14 to 15.5 cm. of water); then its resistance fell gradually to 11 cm., then rose to 14. Note that the gallbladder empties for an average period of 30 minutes, while the sphincter relaxes for an average period of only 17 minutes. (From Boyden, Bergh and Layne: Surgery, 13: 723–33, 1948.)

words, the phase of emptying is brought to a close both by the diminishing contraction of the gallbladder and the increasing resistance of the sphincter. (Should it be asked why the closing of the phase cannot be attributed wholly to the sphincter, instances may be cited in which the gallbladder empties intermittently into the common hepatic duct when the duodenal orifice of the common duct is partially occluded.*)

After the introduction of egg yolk into the duodenum virtually the same time intervals are recorded as when magnesium sulfate is used. The difference is in the magnitude of the response. The sphincter lowers its resistance by 7 cm. of water instead of 3.1, and the gallbladder its volume by 71 per cent instead of 43 per cent. Therefore it is difficult to escape the conclusion that magnesium sulfate, like egg yolk, induces the formation of a hormone which acts directly upon both gallbladder and sphincter. During fasting the tone of the sphincter is maintained, presumably, by a local nerve net which sustains a higher threshold than that of the gallbladder. This is consistent with the fact that it can be relaxed by antispasmodic, but not by neuromimetic drugs.

What is the evidence that sphincteric action is due to an intrinsic musculature and not to the muscularis of the duodenum? First, Schwegler and Boyden** have shown that the sphincter develops much later in human embryos than the duodenal muscle, and that it arises by progressive differentiation of the mesenchyme around the intramural portion of the ducts. Second, Bergh and Layne‡ have demonstrated, by a manometer in the common duct and a balloon in the duodenum, that the sphincter can act independently of the duodenal musculature and that spasms of the sphincter give rise to pain resembling that of biliary colic.

The arrangement of muscle fibers about the duodenal portions of the bile duct is complex, as might be expected. The bile and pancreatic ducts enter the duodenum through an eye-shaped slit in the circular muscle of the gut. (See interval between *Margo sup.* and *Margo inf.*, Fig. 465, *A*, *C*). At this point fibers reinforce the angles of the fenestra, thereby preventing extension by splitting (Fig. 465). Other fibers connect the margins of the fenestra, and the hiatus in the longitudinal muscle, with the major papilla and its ducts, and serve both to erect the papilla and to anchor the ducts to the aperture.

As soon as the bile duct enters the duodenum it begins to taper, so that stones are frequently lodged at this point (Fig. 465) From the fenestra to its junction with the pancreatic duct the bile duct is surrounded by an intrinsic sheath of circular muscle, the sphincter choledochus. The latter is the principal occluding apparatus, responsible for the filling of the gallbladder between meals. Also it hypertrophies frequently when calculi enter this portion of the duct, and may prevent stones from passing, thus leading to the formation of a fistula in the major papilla through which large stones escape into the gut. Where the ducts lie side by side, the choledochal sphincter may interlace with an inconstant sphincter pancreaticus (Fig. 465, *B*) in a manner suggesting the form of the numeral 8.

Around the two ducts, just before they unite to form the ampulla (Fig. 466), is a peripheral sheath of muscle fibers which encircle both ducts. This is the beginning of the sphincter ampullae; it extends nearly to the end of the papilla. When this becomes spastic, it creates a common channel between bile and pancreatic ducts. If the ducts empty separately (Fig. 464, *B*), the sphincter ampullae is replaced by a sphincter papillae. Mann and Giordano§ found an ampulla 3 mm. or more in length in 20 per cent of 200 consecutive necropsies. This corresponds to the percentage of choledochotomized patients in whom there is a reflux of contrast media from the bile into the pancreatic ducts.‖ Recently Howe and Bergh¶ showed that, in twenty-five out of twenty-seven patients exhibiting such a reflux, the serum amylase rose above 200 Somogyi units, indicating the existence of a pancreatitis presumably caused by influx of bile.

Finally there are two longitudinal fascicles, running lengthwise of the papilla in the intervals between the two ducts. In addition to fibers which connect the papilla with the margins of the fenestra, these fascicles contain

* Boyden and Layne: Gastroenterology, 4: 121–34, 1945.
** Anat. Rec., 67: 441–46; 68: 17–41, 193–220, 1937.
‡ Am. J. Physiol., 128: 690–94, 1940; Surg., Gynec. & Obst., 70: 18–24, 1940.
§ Arch. Surg., 6: 1–30, 1923.
‖ Logan, Proc. Soc. Exper. Biol. & Med., 38: 808, 1938.
¶ Gastroenterology, 16: 309–17,

bands which pass between different transverse levels of the ducts and ampulla; these serve mainly to shorten and erect the papilla.

The rate of emptying of the gallbladder is much faster in boys than in girls, but the rate is reversed after puberty (Table 3). Emptying is faster in ulcer patients, and delayed in pregnancy and in patients with pernicious anemia.

Cholecystograms of patients with peptic ulcer indicate that, at least in men under forty, and probably in older men as well, the ulcerous condition markedly increases the rate of evacuation of the gallbladder.* Rigler and Boyden (unpublished studies) have found that this is due to the faster initial discharge of egg yolk from the stomach.

During the first three months of pregnancy the rate of emptying of the gallbladder is not significantly different from the normal rate; however, in the second and third trimesters there is a marked retardation in flow, the mean discharge in thirteen cases being only 52 per cent (forty minutes post cibum) as against the normal nulligravid mean of approximately 73 per cent.** This is not due to any delay in the initial rate of emptying of the stomach‡. Even more significant is the comparison of the rate of emptying in the same person before and after parturition. The mean discharge forty minutes post cibum in five patients subjected to this test was only 38 per cent during pregnancy as against 71 per cent six to eight weeks post partum. This initial delay in the response is attributed to a hypertonic condition of the sphincter choledochus, that is, to a physiologic

* Boyden and Berman: Radiology, 28: 273–82, 1937.

** Gerdes and Boyden: Surg., Gynec. & Obst., 66:145–56, 1938.

‡ Boyden and Rigler: Proc. Soc. Exper. Biol. & Med., 56: 200–201, 1944.

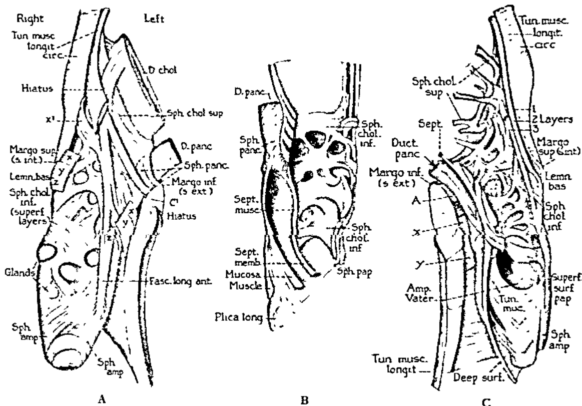


Fig. 465. MACERATED PREPARATIONS, SHOWING PAPILLA AFTER REMOVAL OF TUNICA MUCOSA (× 5).

A, Anterior view of choledochoduodenal junction with tunica mucosa removed. *Margo sup.* and *inf.*, margins of slit in circular muscle (Fen. Chol.) through which bile and pancreatic ducts enter the duodenum; *Hiatus*, slit in longitudinal muscle of gut. The anterior longitudinal fascicle and fibers connecting the ducts to the gut wall are most conspicuous in views of the surface of the papilla. Yet outer layers of the sphincters are visible. To see the principal bundles of the sphincter choledochus, it is necessary to split the papilla lengthwise and dig out the mucosa of the ducts. *B*, Bisected papilla of type in which the ducts empty separately. *C*, Bisected papilla of type in which the ducts empty into an ampulla of Vater. (Boyden: Surg., Gynec. & Obst., 104: 641–52, 1957)

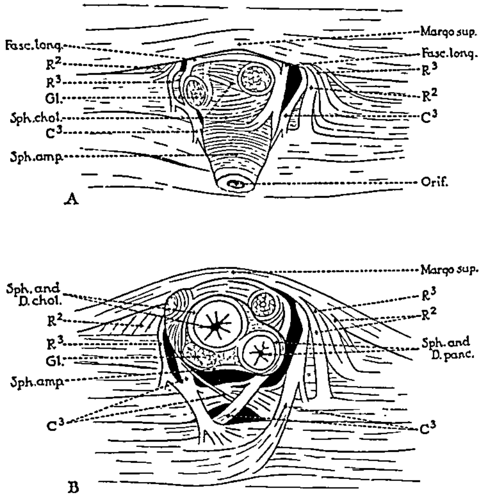


Fig. 466. MUCOSAL SURFACE OF MAJOR PAPILLA, ILLUSTRATING MAXIMUM DEVELOPMENT OF SPHINCTER AMPULLAE (× 4.5).

A, Papilla lying in natural position after removal of mucosa. *B*, Papilla elevated, with distal half snipped off, to show underlying fibers and the relation of sphincters to ducts. Abbreviations: *Gl.*, glandular masses exposed by maceration and dissection; *C³ and R², R³, bands of* "connecting" and "reinforcing" fibers; *Sph. amp.*, beginning of sphincter ampullae. (From Kreilkamp and Boyden: Anat. Rec., 76: 485–97, 1940.)

Table 3. Sex Differences in Emptying of Human Gallbladder

(Boyden: Anat. Rec., 40: 147–84, 1928.)

	Age (*Years*)	*Weight* (*Pounds*)	*Volume of Gall-bladder Before Meal* (*cc.*)	*Percentage of Bile Discharged at* 15′ pc. (*cc.*)	30′ pc. (*cc.*)	45′ pc. (*cc.*)	*Minimum Time Required to Empty All But 3 cc. of Bile* (*Minutes*)	*Volume of Smallest Cholecystogram* (*cc.*)
Average for 12 women	24¼	131.3	26.8	48.3%	73.6%	79.8%	68.5	1.33
Average for 12 men	25¼	151.1	30.8	32.8%	52.3%	64.0%	128.5	2.21
Average for 24 cases	24¾	141.1	28.8	40.5%	62.9%	71.9%	98.5	1.77

dyskinesia reflecting a hormonal imbalance in pregnancy. The resulting biliary stasis accounts for the distended gallbladders frequently found at term in cases of cesarean section, and for the thick, tarry contents of gallbladders at term which are characterized by a low bile-salt (and a high cholesterol) concentration comparable only to that found in vesicles with a damaged wall. It is further believed that the stasis of pregnancy sets the stage for the sequence of events which results in the greater incidence of gallstones among women that have borne children.

It is regarded as probable that damage to the biliary duct system occurs in the early stages of pernicious anemia.* And, since in females there is a highly significant retardation in emptying (the gallbladders having discharged an average of only 69 per cent of their contents in the first forty minutes after a standard meal as against the 84 per cent in the controls), it is suspected that the stasis induced by pregnancy contributes to damage of the gallbladder. In stasis resulting from either condition, or from both in combination, the increased excretion of biliary pigment, with consequent damage to the gallbladder wall, may be one of the chief contributory factors in the etiology of the concomitant cholecystic disease.

VESSELS. The arteries surgically related to the extrahepatic bile passages are derived from the common hepatic trunk of the celiac axis. The hepatic artery divides early in its course behind the pylorus into two diverging trunks, the hepatic artery proper and the gastroduodenal artery (Figs. 467, *b*; 468, *a*).

The *hepatic artery proper* runs superiorly to the right in the lesser omentum (hepatoduodenal ligament); during its course it gives off the right gastric artery to the pyloric side of the lesser curvature. Near the liver the hepatic artery divides into right and left branches for the corresponding liver lobes. The cystic artery usually arises from the right hepatic branch and runs to the cystic duct and the neck of the gallbladder. In the majority of cases the right branch of the hepatic artery lies to the right of the hepatic duct, so that the cystic artery does not cross it. Variation, however, in origin of the hepatic artery, or arteries, is common (Fig. 437), as is also the derivation of the cystic artery (Fig. 468).

* Boyden and Layne: Gastroenterology, 4: 121–34, 1925.

On the basis of data gathered from examination of 600 specimens, the types of origin of the cystic artery may be placed in four categories (Figs. 467, 468).

In those specimens which might be placed in a first (and most numerous) category, the cystic artery arose from a division of the hepatic artery, the latter at the point of division, or the same vessel proximal to the point of bifurcation (Fig. 468, *a* to *d*). In succession, and in the order of decreasing frequency, these are as follows: from the right ramus of the hepatic artery proper in 415; from the latter vessel at the point of division in seventy-eight; from the left ramus in forty; and from the hepatic artery proper, proximal to the point of bifurcation, in twenty-three. Totally, 556 for the four near source vessels.

To a second category may be assigned those specimens in which the cystic artery takes origin from the downwarded vessel, the gastroduodenal artery, or a branch of the latter, the superior pancreaticoduodenal (Fig. 468, *e*, *f*); origin from the more distant source is far less common (one case) than from the nearer (seventeen instances).

In a third general group belong those specimens in which the immediate source of the cystic artery matches the general pattern which exists in the cases illustrated in the first category, but differs from them in the derivation of the parent vessel (Fig. 468, *g*, *h*). The parent stem may be the superior mesenteric in each, but the hepatic artery may be either an accessory artery or a replacing one. Together, these total ninety. From one point of view, they could be regarded as belonging in the first category (to make a new total of 646).

To the last, or fourth, category may be assigned those specimens in which the cystic artery is "moved," so to speak, toward the aorta (Fig. 468, *i* to *l*). These have been observed in four types: from the right gastric (in one case); from the hepatic artery near the celiac source (in three instances); from the celiac itself (in two cases); and from the superior mesenteric (in six instances). Together these cases number but twelve.

The *gastroduodenal artery* runs downward and backward along the mesial concave margin of the descending duodenum to the left of the common duct. The interlacing branches given to the common duct must be kept in mind in operations on its supraduodenal and retroduo-

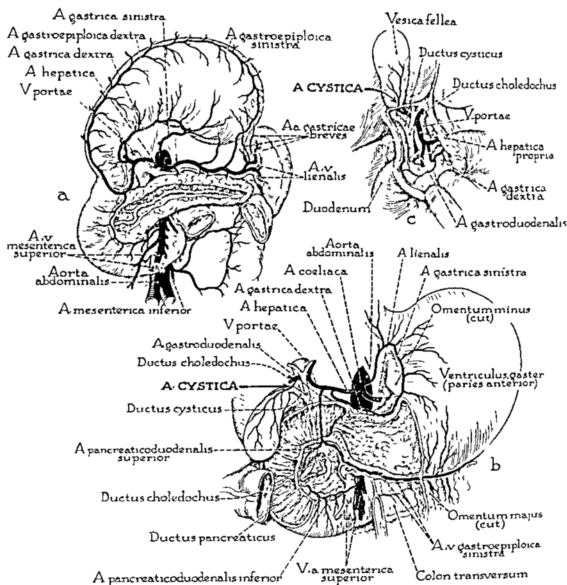


Fig. 467. BLOOD SUPPLY OF THE STOMACH, LIVER, GALLBLADDER AND RELATED ORGANS.

a, The branches of the celiac artery, exposed by lifting the stomach upward. The stomach is shown without its omental supports, in order to present more graphically the pattern of triradiate division and subsequent distribution of the celiac branches. *b*, The branches of the hepatic division of the celiac artery, shown with the stomach restored to natural position. Here the artery to the gallbladder is derived from the right ramus of the hepatic artery proper. *c*, The relation of the biliary ducts to the blood vessels, as seen upon dissection of the anterior layer of the hepatoduodenal ligaments.

Typically, as here shown, the celiac artery gives rise to 3 branches; namely, the left gastric (to the lesser curvature of the stomach, chiefly), the lienal (which courses transversely toward the left hypochondrium) and the hepatic. The last vessel, passing upward and to the right, separates into two division, the gastroduodenal (downward) and the hepatic proper (upward). The cystic artery arises most frequently from the latter's right ramus. (From Anson: Quart. Bull., Northwestern Univ. M. School, 30: 250–59, 1956.)

denal portions. Its terminal branches are the right gastro-epiploic and the superior pancreaticoduodenal arteries (Figs. 467, *b*; 468, *a*).

The *portal vein* and its relations have been considered (Fig. 436).

The *lymphatics* of the gallbladder and cystic duct drain not only to the lymph nodes at the hilus of the liver, but also along lymph channels into the liver substance. By the latter efferent vessels the liver may be infected from a diseased gallbladder. The lymph vessels along the hepatic and common ducts drain into nodes along the common duct, which, when hypertrophied, feel like calculi in the common duct.

Surgical Considerations

The various congenital anomalies of extrahepatic parts of the biliary tract are features of concern to the roentgenologist and the surgeon

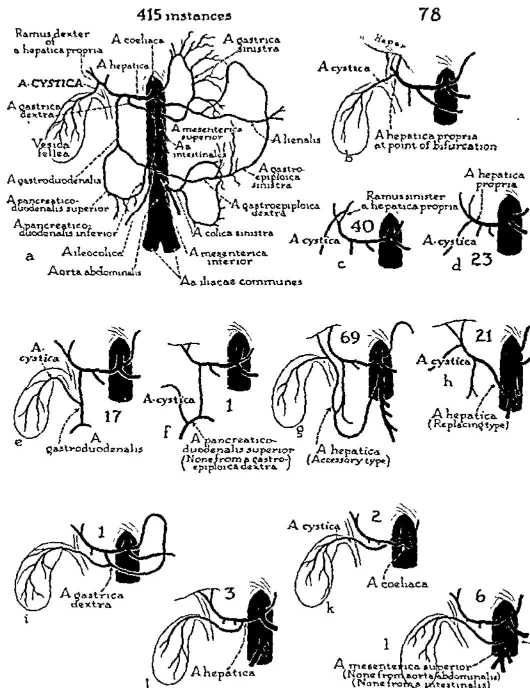


Fig. 468. BLOOD SUPPLY OF THE GALLBLADDER.

Variations in origin, recorded in instances encountered in a study of 600 specimens. Owing to the occurrence of supernumerary cystic arteries, the total number of vessels exceeds the number of cadavers studied (676 and 600, respectively). It is to be noted that the commonest vessel of source is that which is closest to the gallbladder. (From Anson: Quart. Bull., Northwestern Univ. M. School, 30: 250–59, 1956.)

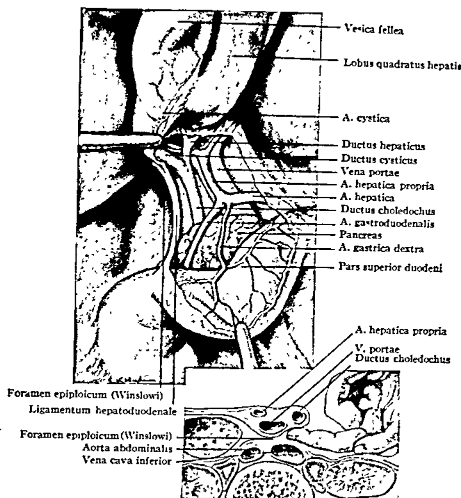


Fig. 469. TOPOGRAPHY OF THE VESSELS AND DUCTS IN THE HEPATIC PEDICLE, AND METHOD OF STOPPING BLEEDING FROM THE HEPATIC ARTERY.

Considerable variation occurs in the structures of the hepatoduodenal ligament. While the portal vein lies appreciably to the left of the common duct and at a deeper level, its identification should always be established before incision by aspirating for bile through a small needle. Inserting a finger through the foramen of Winslow and lifting up on the hepatoduodenal ligament will stop bleeding from the hepatic or cystic arteries.

(Figs. 437, 452, 455 to 458). Generally speaking, anomalous conditions of the gallbladder are conducive to pathology. In some instances the aberrant form or position is the basis of symptoms correctable only through surgical intervention. Thus floating gallbladder may become twisted, with resultant infarction from impairment of the blood supply; a displaced organ presents a problem in identification; a calculus may form in the cul-de-sac of a gallbladder of diverticular type. On the other hand, absence of the gallbladder does not impair the patient's digestive functions. In a review of 400 cases of atresia of the extrahepatic biliary passages recorded in the literature, approximately one sixth had an associated absence of the gallbladder; in addition to these, no less than thirty-eight cases have been described in the literature in which, in the presence of normal hepatic and common bile ducts, absence of the gallbladder was the only abnormality noted (Gross).

The most common operation on the gallbladder is cholecystectomy. It can be easy or difficult, depending upon the ease of gallbladder exposure and the extent of the inflammatory process. *The surgeon must realize that anatomic variations of the structures in the hepatoduodenal ligament are common, and nothing in that area should be clamped by a hemostat or incised until it is definitely identified* (Figs. 437, 440, 441, 452, 455 to 457, 467, 468).

As for other laparotomies, before beginning removal of the gallbladder, the condition of other abdominal viscera should be learned by inspection or palpation, or by both methods.

The subhepatic space (Fig. 469) lateral to the foramen of Winslow is dependent to the

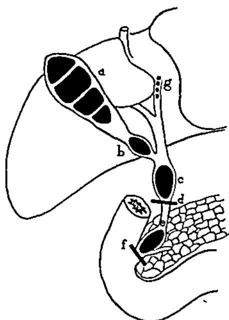


Fig. 470. SCHEMA OF THE LOCATION OF CALCULI AND TUMORS IN THE EXTRAHEPATIC BILE PASSAGES.

a, Faceted gallstones in the gallbladder; *b*, solitary stone in cystic duct; *c*, stone in supraduodenal part of the common duct; *d*, tumor obstruction of common duct; *e*, stone in pancreatic portion of common duct; *f*, tumor of intraduodenal part of common duct; *g*, small calculi in left primary hepatic duct. (After De Quervain.)

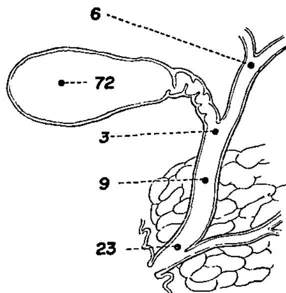


Fig. 471. SITES OF ORIGIN OF CARCINOMA IN THE EXTRAHEPATIC BILIARY TRACT.

In the order of decreasing frequency, in 113 cases, the sites of cancer were as follows: gallbladder, 72; ampulla of Vater, 23; common bile duct, 9; common hepatic duct, 6; cystic duct, 3 (From Glenn and Hill: Cancer, 8: 1218-25, 1955.)

gallbladder and ideal for the site of a small drainage tube after gallbladder operations.

When a calculus becomes impacted in the cystic duct (Fig. 470), or when the duct is occluded by a cicatricial contraction, the gallbladder becomes distended by the clear mucinous fluid secreted by its mucous membrane and forms what is called a *hydrops of the gallbladder*, often erroneously referred to as filled with *white bile*. The surgical significance is that, when a hydrops or "white bile" is found at operation, the obstructing cystic duct stone must be removed when the gallbladder is removed. To leave a small stone in a cystic duct stump is to encourage postcholecystectomy pain.

If suppurative cholecystitis is superimposed upon a hydrops, the gallbladder will also contain pus to the extent of forming an abscess sac (empyema).

APPROACH TO THE GALLBLADDER. The most commonly used surgical approaches to the gallbladder are, first, the right upper quadrant vertical paramedian (Fig. 357, *C*) and the transverse (Fig. 376, *D*). The author (W.G.M.) prefers the latter because it gives more direct vision to the gallbladder area and allows easier dissection and identification of the common bile duct and other structures in the hepatoduodenal ligament, thus avoiding injury in this area.

A few surgeons prefer the subcostal incision (Fig. 357, *A*), but this, as shown in Figures 350 and 351, cuts too many intercostal nerves, at least the ninth and tenth, and probably the eleventh.

CHOLECYSTOSTOMY. Drainage of the gallbladder (Fig. 472) is occasionally done when a severe inflammatory process involves the gallbladder, or when the condition of the patient for one reason or another makes the preferable cholecystectomy hazardous. About half of such patients will have recurrent symptoms necessitating removal of the gallbladder later.

CHOLECYSTECTOMY. The most common indication for removal of the gallbladder (Fig. 473) is subacute or chronic cholecystitis with or without stones (cholelithiasis). Some surgeons perform cholecystectomy in the early stages of acute cholecystitis, believing (1) that the operative procedure is easier if done before marked evidence of pericholecystic and pericholedochal inflammation has developed, and (2) that by early operation a possible diagnostic

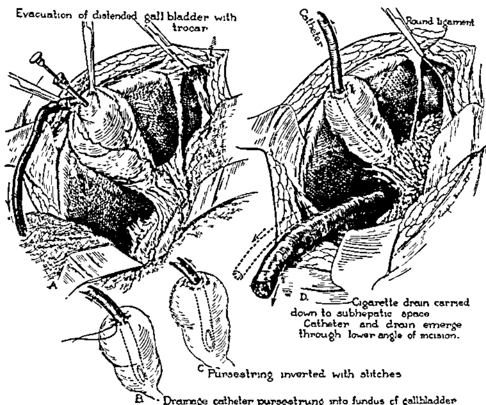


Fig. 472. CHOLECYSTOSTOMY.

A good approach for this operation is provided by a somewhat smaller than usual transverse or subcostal incision (Figs. 356, *A;* 357, *C*). The surrounding structures are carefully packed off to prevent contamination. *A,* The gallbladder is evacuated with an aspirating trocar, or suction after a small incision in the fundus. The puncture wound is then enlarged and the cavity searched for calculi. *B* and *C,* A soft rubber drainage tube 1 cm. in diameter, or a large catheter, is inserted into the gallbladder, and the wound closed about it with a purse-string suture. *D,* A cigarette drain or, better, a small soft rubber drain is inserted to the subhepatic space just outside the foramen of Winslow. This drain and the tube in the gallbladder are then brought out of the lateral angle of the wound.

error, such as allowing an acute appendicitis to progress, is obviated. The gallbladder is also removed for various degrees or complications of the following: chronic empyema, distention or hydrops of the gallbladder due to blockage of the cystic duct by a stone or stricture, gangrene of the viscus, chronic pancreatitis associated with cholecystitis, calcareous degeneration and cholesterolosis of the gallbladder, and malignant tumors confined to the gallbladder (Fig. 471).

Removal from the fundus downward affords free anatomic dissection, and is indicated when the neck of the gallbladder is more or less hidden by dense adhesions. Incision is made through the serous and subserous layers along each side of the gallbladder and over the fundus at a sufficient distance from the liver attachment to afford peritoneal covering for the cystic fossa after the viscus has been removed. The fundus is drawn downward from the liver and separated from it by blunt dissection. As the dissection is carried toward the neck of the bladder, the cystic artery is seen beside the cystic duct. The artery and duct are exposed and followed into the hepatic pedicle, where the artery is ligated and divided proximal to its division into terminal branches. The peritoneal flaps are sutured across the raw surface of the liver bed.

The more common approach is to carry the *dissection from the cystic duct upward,* so that the most difficult steps in the operation are completed at once. Isolation, ligation and division of the cystic duct and artery create a bloodless field for removal of the gallbladder. In the event of hemorrhage in the depth of the wound, compression of the hepatic pedicle between the thumb and forefinger will arrest the hemorrhage by occluding the hepatic artery. The bleeding vessel, generally the cystic artery, then can be looked for in a dry field.

CHOLEDOCHOTOMY. This operation is designed for exploration of the common bile duct

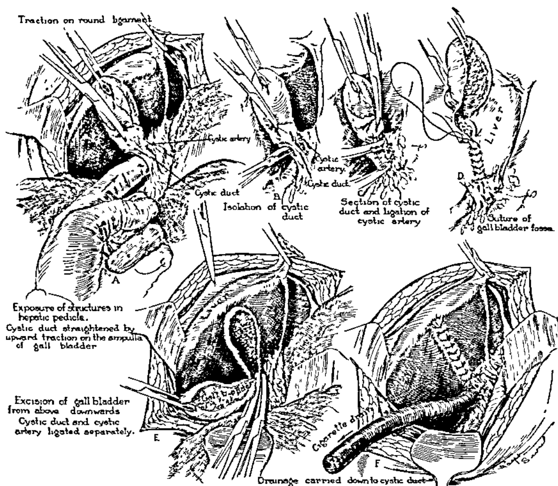


Fig. 473. CHOLECYSTECTOMY.

The gallbladder is usually removed by *dissection from the cystic duct upward. A*, This requires good exposure of the hepatoduodenal ligament structures. The common bile duct is developed, and its size, color, thickness of wall, and presence or absence of stones noted. *B*, The cystic duct is isolated. *C*, The cystic duct is clamped, divided and ligated. The cystic artery is ligated and divided. The gallbladder is then dissected from below upward. *D*, Denuded fossa peritonealized to lessen chance of adhesions to duodenum or stomach. *E*, *Dissection of gallbladder from fundus downward.* This is often done when severe inflammatory reaction and edema are present. The neck of the gallbladder is commonly bound down with old and recent adhesions. The field is bloody because the dissection of the gallbladder from the liver bed is done before the cystic artery is ligated. *F*, Gallbladder bed peritonealized and cigarette or, better, small soft rubber drain to subhepatic space.

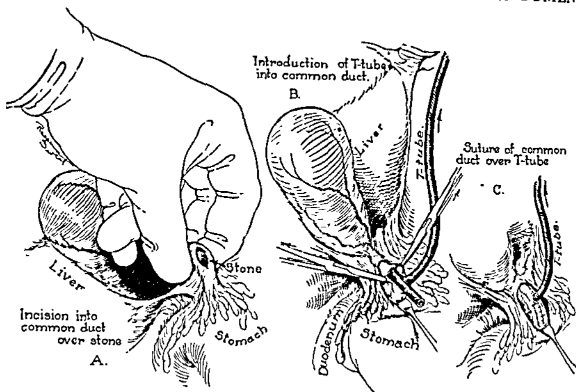


Fig. 474. CHOLEDOCHOTOMY WITH COMMON DUCT DRAINAGE.

Note that the gallbladder has not been removed. Traction on it upwards aids in exposing the common bile duct. After the incision in the common duct has been sutured about the T-tube the gallbladder is removed in the usual fashion.

if there is a history suggestive of, or evidence of, obstruction in the duct due to calculi (Fig. 470). Important factors in making the decision to do a choledochotomy are (1) jaundice—past or present; (2) stones felt along the common duct; (3) dilated or thickened common duct; (4) small stones in the gallbladder; (5) sediment in bile aspirated from the common duct; (6) noncalculous gallbladder with symptoms of colic; (7) persistent postcholecystectomy pain; and (8) acute or subacute pancreatitis. Obstruction resulting from malignant growths is a different problem (Fig. 471).

In *supraduodenal choledochotomy* the common duct is incised longitudinally in the free portion between its origin at the junction of the cystic and hepatic ducts and the upper margin of the duodenum. Through this opening the duct may be searched carefully with probes and catheters, and flushed with saline solution as far downward as the ampulla of Vater and upward into the hepatic radicles in the search for calculi. After completion of the exploration the choledochotomy opening is closed about a small T-tube (Fig. 474) or catheter for drainage of the biliary system (cholecystostomy).

Transduodenal choledochotomy is commonly done for exploration of the lower common duct and ampulla of Vater area, usually for stones (Fig. 475). The lower part of the second portion of the duodenum is opened in a longitudinal fashion and a sphincterotomy done, usually for stones, but occasionally for stricture or stenosis of the ampulla. Some surgeons advise against sewing the edges of the ampullary area to the common duct because the suture may catch and close off the pancreatic duct. Usually a T-tube is placed in the supraduodenal common bile duct, but it should not be a tightly fitting tube, since such might cause necrosis. The use of a long armed T-tube, the long arm going through the open sphincter into the duodenum, has been followed by fatal pancreatitis, probably by being too tight and blocking the pancreatic duct. As in other fluid systems in the body, free drainage is necessary.

CHOLECYSTENTEROSTOMY. An anastomosis between the gallbladder and the duodenum or a loop of jejunum is often done to by-pass an inoperable obstruction of the common duct, such as is encountered in tumors of the head of the pancreas, of the common duct, or ampulla of Vater. The operation is a palliative short-circuit bringing bile down from the gallbladder to the intestinal tract.

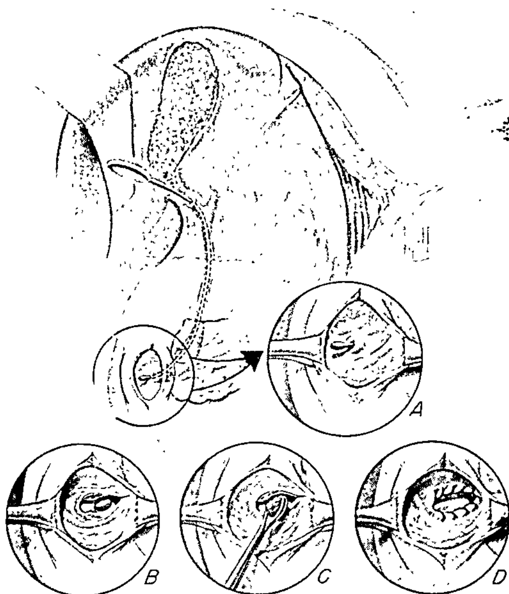


Fig. 475. TRANSDUODENAL AMPULLO-DUODENOSTOMY FOR TREATMENT OF COMMON BILE DUCT OBSTRUCTIONS.

Small malleable probe passed downward through stump of cystic duct has by-passed pocketed stone at distal end of common bile duct. *A*, Incision in second portion of duodenum exposes papilla of Vater, identified by protruding probe. *B*, By using probe as guide, incision is made through the sphincter of Oddi into the ampulla of Vater, exposing impacted stone. *C*, Stone removed under direct vision with forceps. *D*, Edges of duct sutured to edges of duodenal mucosa for internal drainage of biliary tract. (From Preston: Surg., Gynec. & Obst., 100: 498–502, 1955.)

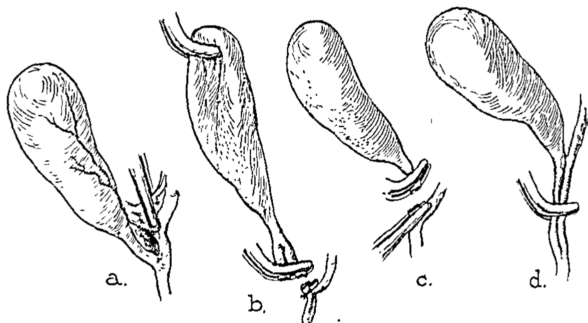


Fig. 476. WAYS OF INJURING THE EXTRAHEPATIC BILIARY DUCTS AT OPERATION.

A, Quick snapping at a hemorrhage from the cystic artery area in a field obscured by blood. *B*, Too much traction on the gallbladder with knuckling of the common duct, and the forceps applied too low. *C*, Cystic duct clamped too close to the common duct. A tie will then completely obstruct the duct. *D*, Inadvertent clamping of the long cystic duct closely adherent to the common hepatic duct. (Modified from Cattell: S. Clin. North America, 23: 701–13, 1943.)

INJURIES TO THE EXTRAHEPATIC BILIARY DUCTS. Operative injury to these ducts is one of the tragedies of gallbladder surgery and is the cause of 80 per cent of the cases of benign stricture of these structures. Inflammatory processes make up the other 20 per cent.

The surgeon must be cognizant of the fact that variations in the pattern of the extrabiliary duct and arterial system commonly occur and may lead to division or ligation of the wrong structure (Figs. 455 to 457, and 476). As stated before, *no structure in the hepatoduodenal ligament should be clamped or incised until it has been positively identified.*

Copious bleeding from the cystic artery may be troublesome at times, and hasty attempts to grasp the vessel in a pool of blood often lead to clamping of the common hepatic duct or common bile duct. Hemorrhage in this area can always be stopped by pressure with a sponge or, if more serious, by inserting a finger in the foramen of Winslow and lifting upwards. This will close off the hepatic artery and stop the bleeding. Then with good exposure and suction to remove the blood, the actual bleeding point is easily seen and a hemostat can be placed on the bleeding vessel. Careless handling of the cystic and other extrahepatic biliary ducts may result in damage obstructing the flow of bile, the situation later leading to multiple operations attempting to relieve the obstruction. The mortality rate in such cases is high.

PANCREAS

DEFINITION AND LOCATION. The pancreas is an elongated, hammer-shaped gland, closely resembling in outward appearance one of the larger salivary glands (Fig. 477). It lies in the epigastrium and left hypochondrium in an ultimately retroperitoneal position behind the serous floor of the omental bursa (lesser sac), at the level of the first and second lumbar vertebrae. Its deep location explains the difficulty in clinical diagnosis between inflammatory and tumor involvement of the gland, and lesions of the overlying stomach, transverse colon, and omentum. Adding to the confusion with lesions of other supramesocolic viscera is the fact that lesions of the pancreas are prevented from posterior extension by the resistant posterior abdominal wall, and extend forward into the lesser sac. Furthermore, since the anterior surface of the organ is covered by peritoneum forming the floor of the lesser peritoneal sac, an acute inflammation of the pancreas may cause a peritonitis with effusion, which, at first, is limited to the lesser sac. If the epiploic for-

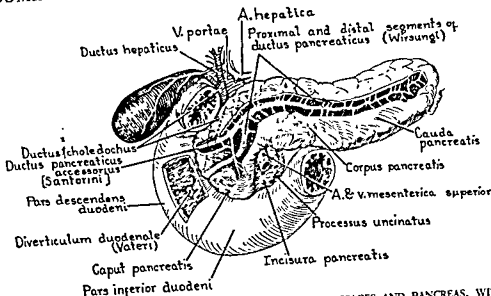


Fig. 477. NORMAL RELATIONS BETWEEN THE DUODENUM, BILE PASSAGES AND PANCREAS, WITH SPECIAL REFERENCE TO THE PANCREATIC DUCTS.

amen is blocked simultaneously by inflammatory adhesions, the exudate will be confined to this region and will give the physical signs of a tumor.

DIVISION AND RELATIONS. The pancreas is divided into a head, neck, body, and tail (Fig. 477). The *head* or right extremity is embraced by the duodenum and bends downward over the duodenum for some distance below the general level of the gland. This intimate relation to the duodenal loop, particularly to its descending portion, explains how lesions of the head of the gland, notably carcinoma, may encroach upon the lumen of the duodenum and cause obstructive symptoms necessitating gastrojejunostomy. A rare anomaly has been observed in which the head of the pancreas surrounds the duodenum like a ring (Fig. 482). By the swelling of chronic pancreatic inflammation, this arrangement may lead to actual stenosis of the duodenum. Anteriorly, the head is covered by the pylorus above and the transverse colon below. The root of the transverse mesocolon divides the head into supramesocolic and inframesocolic areas. Posteriorly, the head is related to the inferior vena cava, left renal vein, and aorta. Tumors of the gland may compress the inferior vena cava and the portal tributaries, causing edema of the extremities, and ascites. The common bile duct, near its termination, lies in a groove at the right extremity of the gland and may be embedded in it. This explains the jaundice from biliary retention in chronic pancreatitis and in carcinoma of the head of the gland. In obstruction caused by carcinoma of the head of the pancreas the gallbladder (in 50 per cent of the cases) is distended by the gradual accumulation of bile (Fig. 480); whereas, in obstruction resulting from gallstones, the gallbladder rarely is distended—Courvoisier's Law. The uncinate process of the head of the pancreas hooks behind the superior mesenteric vessels (Fig. 477).

The *neck* is a comparatively short, narrow portion directed upward and to the left to join the body. It supports the pyloric end of the stomach. At its upper border the common duct, portal vein and hepatic artery enter the gastrohepatic (lesser) omentum; behind the neck the superior mesenteric and splenic veins unite to form the portal vein.

The *body* of the pancreas forms a well-marked anterior convexity where it lies in front of the vertebral column at, or a little below, the transpyloric plane. It is somewhat triangular in cross section and presents three surfaces. The anterior surface is covered by the peritoneal floor of the omental bursa. An ulcer on the posterior wall of the stomach may adhere to this surface of the gland and penetrate its substance. A solid or cystic pancreatic tumor will bulge forward through the overlying peritoneum and present through the gastrohepatic (lesser) omentum, gastrocolic ligament or transverse mesocolon. These modes of

presentation constitute the rationale for the surgical approaches to the organ.

The inferior surface is separated from the anterior surface by the anterior border of the gland, along which lies the attachment of the root of the transverse mesocolon. The underlying splenic vein and left renal vessels indicate the danger of attempting to reach the pancreas by a posterior lumbar approach. The upper margin of the body of the pancreas has a close relation with the celiac trunk, and is grooved or tunnelled by the splenic artery.

Without demarcation, the body merges into the *tail*, which usually lies within the peritoneal duplication of the lienorenal ligament and is related below to the left colic flexure. When the tail is short, it does not reach the hilus of the spleen; when long, it lies at the hilus, surrounded by the splenic vessels. These intimate relations of the pancreas and spleen should always be considered in splenectomy (p. 497), since a ligature placed *en masse* on the splenic vessels easily may include the tail of the pancreas.

Duct System of the Pancreas. The *main pancreatic duct* (of Wirsung) begins in the tail and traverses the whole gland near its posterior surface, receiving branches from all sides. It emerges from the right border of the head and, together with the common bile duct, opens into the ampulla of Vater. An *accessory pancreatic duct* (of Santorini) drains the upper part of the head of the gland, opening by one extremity into the main pancreatic duct and by the other into the duodenum, cephalad to the opening of the main duct (Fig. 477). Numerous variations in the size and connections of the main and accessory pancreatic ducts occur. The accessory duct may convey all the pancreatic secretion to the duodenum in the event of obstruction to the terminal part of the main duct. During excision of a posterior penetrating duodenal ulcer, accidental opening into the accessory pancreatic duct occasionally occurs with resulting pancreatic fistula. These fistulae usually heal spontaneously.

The chief point of surgical interest lies in the relation of the common bile duct to the main pancreatic duct (Fig. 461). The common duct traverses the wall of the duodenum obliquely and ends in an ampulla and sphincter (of Oddi). The sphincter guards the outlet of the common duct into the duodenum and controls the bile outflow. In three quarters of cases the pancreatic duct empties into the common bile duct just above, or at the site of, the ampulla, affording a common channel for bile and pancreatic juice. An impaction of a calculus at the ampulla of Vater converts the two ducts into a continuous passage. It is demonstrated fairly well that this mechanism accounts for the passage of bile into the pancreatic duct, which, in dogs at least, will cause pancreatitis.

The pancreas elaborates two secretions, an internal and an external. The external secretion pours into the duodenum the enzymes trypsin, amylase, steapsin, renin and maltase, which are concerned with protein, carbohydrate and fat metabolism. As a result of resections of the head of the pancreas, many patients may do fairly well without the presence of the external pancreatic secretion.

The internal secretion, insulin, is elaborated by the islands of Langerhans, and is necessary for the normal metabolism of carbohydrates. Total pancreatectomy has been performed in human beings, and the relatively mild diabetes which results can be easily controlled with 15 to 25 units of insulin daily.

Vessels of the Pancreas. From a study of 150 dissections Woodburne and Olsen find that, despite the occurrence of variation, there is considerable regularity in the pattern of arterial blood supply to the pancreas (Fig. 478). Two arterial arcades supply the duodenum and head of the pancreas. The anterior arcade is formed by the constant anterior superior pancreaticoduodenal artery from the gastroduodenal artery anastomosing with an almost constant anterior inferior pancreaticoduodenal artery from the superior mesenteric system; the posterior arcade is contributed to from above by the posterior superior pancreaticoduodenal artery (a proximal branch of the gastroduodenal artery) and an almost constantly occurring posterior inferior pancreaticoduodenal artery which arises in over 90 per cent of cases from the superior mesenteric system.

The inferior pancreaticoduodenal vessels are much more variable in the detail of their origin than the superior vessels. A dorsal pancreatic artery occurs in 90 per cent of cases; although typical in course and in branching, its origin is variable (from the splenic, the celiac, the superior mesenteric or the hepatic artery). Its right branch crosses the head of the pancreas to form a prepancreatic arterial arcade

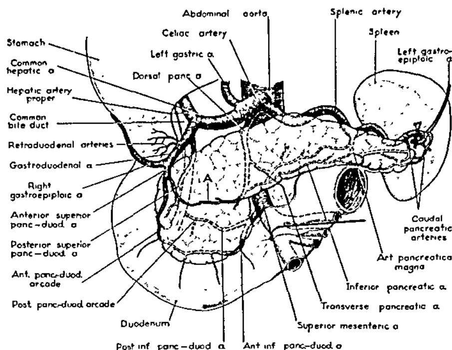


Fig. 478. GENERAL PATTERN OF PANCREATIC ARTERIES.

Symbol "A" is a small but almost constant arcade of pancreatic arteries. (From Woodburne and Olsen: Anat. Rec., 111: 255–70, 1951.)

(incidence, 93.3 per cent) by means of an anastomosis with the left branch of the anterior superior pancreaticoduodenal artery. The constant inferior pancreatic artery is found along the dorso-inferior border of the pancreas. It is in the majority of cases (84 per cent) the left branch of the dorsal pancreatic artery. The pancreatica magna is a superior pancreatic branch of the splenic artery which enters the body of the pancreas at the junction of its middle and left thirds (occurrence, 64.7 per cent).

Caudal pancreatic arteries, from the splenic artery itself or from one of its divisions (commonly the left gastro-epiploic artery), penetrate the tail of the pancreas. These branches form anastomoses with rami from the inferior pancreatic and pancreatica magna.

The *veins* of the pancreas join the splenic vein, but a large trunk issues from the dorsal aspect of the gland and runs upward along the left of the common bile duct to join the portal vein. This vessel may be injured in exposure of the pancreatic part of the common duct (Fig. 436).

Scarcely an organ in the abdomen has as extensive a *lymphatic distribution* as does the pancreas. The glands drain into the pancreaticosplenic nodes at the hilus of the spleen, and into the pancreaticoduodenal and pre-aortic nodes near the origin of the superior mesenteric artery.

Surgical Considerations

The deep location of the pancreas and the important structures surrounding it emphasize the difficulties which attend surgical procedures on this organ.

PATHS OF SURGICAL APPROACH. There are three anterior transperitoneal approaches to the pancreas, in addition to the lumbar approach, for the dependent drainage of pancreatic fluid. Access to its superior margin is afforded through the gastrohepatic ligament, but little room is available for operative manipulation by this route. By far the best exposure is gained through the gastrocolic ligament (Fig. 479), which may be incised throughout its breadth, sparing the gastro-epiploic vessels. The gland may be inspected and palpated from the curve of the duodenum to the tail of the pancreas, and is readily available for any operative procedure.

Limited exposure of the pancreas is afforded by an incision through the transverse mesocolon in an avascular area.

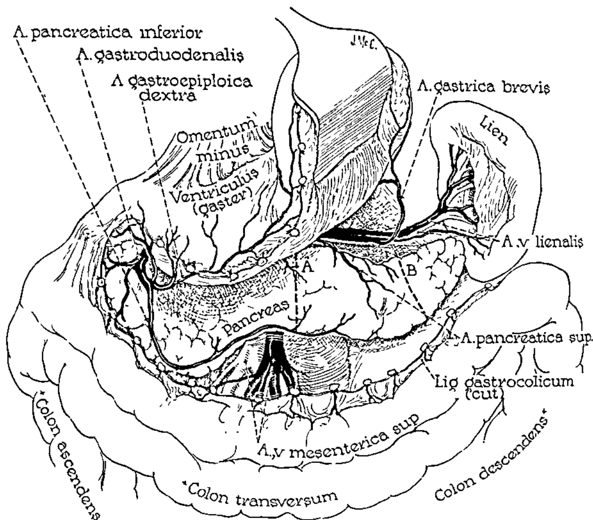


Fig. 479. EXPOSURE OF THE HEAD, BODY AND TAIL OF THE PANCREAS BY DIVIDING THE GASTROCOLIC LIGAMENT.

The gastro-epiploic vessels may be spared. All the pancreas can be carefully examined and palpated. *A* and *B* are levels of electric transection for removal of segments of the body and tail of the gland. The spleen may be elevated and used as a handle to elevate various portions of the body of the pancreas for removal; in such instances the spleen also is removed. This approach gives excellent access to the posterior aspect of the stomach and the splenic vessels. (Modified from Cole: Operative Technic, General Surgery, New York, Appleton-Century-Crofts.)

WOUNDS OF THE PANCREAS. Because of the deep location of the pancreas in the floor of the lesser sac and the protection afforded it by the costal arch, injury to it is exceedingly rare. Occasionally, sharp compression of the abdominal wall over the anterior bodies of the vertebrae has seriously damaged the pancreas. Penetrating wounds involving the stomach require careful investigation of the pancreas, lest a laceration be overlooked and the patient succumb from pancreatic necrosis and peritonitis. Since a pancreatic fistula is prone to follow any injury or operative intervention on the pancreas, a site for drainage should generally be provided.

PANCREATITIS. *Acute hemorrhagic pancreatitis* is a serious condition commonly producing violent epigastric pain, often with shock. The exact etiology is not known, but the following have been strongly suspected of being causative agents: (1) the flow of bile into the main pancreatic ducts (injection of bile into the ducts of dogs reproduces the disease); (2) metaplasia of duct epithelium blocking external secretions; (3) spasms of the sphincter of Oddi; (4) blockage by impacted calculi in the ampulla; (5) infectious processes spreading to the pancreas and the biliary tract, especially from the gallbladder. Since partial or complete necrosis of the gland occurs with a marked serohemorrhagic peritoneal exudate, the treatment at one time was directed towards surgical drainage of the pancreatic area and the performance of a choledochotomy. The morta[illegible] following

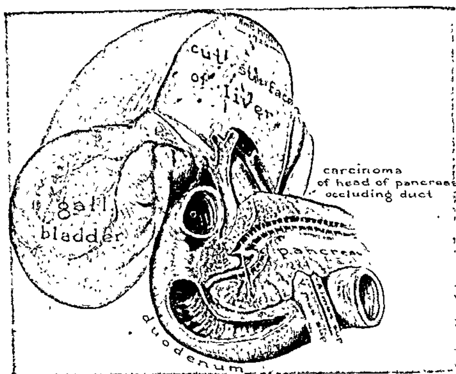


Fig. 480. DISTENTION OF THE GALLBLADDER AND BILIARY DUCTS FROM CARCINOMA OF THE HEAD OF THE PANCREAS OBSTRUCTING THE COMMON DUCT.

(From Babcock: Textbook of Surgery.)

such procedures was close to 50 per cent. Recently, conservative management consisting in support of the shock, gastroduodenal suction if vomiting occurs, absolute rest and large amounts of antibiotics systemically has cut this mortality in half. Early in pancreatitis, blood amylase levels are usually elevated, forming a good differential diagnostic feature.

Acute interstitial pancreatitis is also a severe inflammatory process for which conservative management is now improving on the previous operative treatment. *Recurrent pancreatitis* is a disturbing cause of repeated upper abdominal pain often associated with calcareous deposits in the gland. Resection of the pancreas may be indicated for this severe pain, but recently there has been some evidence that a thoracolumbar sympathectomy alleviates the symptoms.

CARCINOMA OF THE PANCREAS. Carcinoma in this organ occurs 80 per cent in the head, and almost always involves the common bile and pancreatic ducts by pressure or invasion, or both (Fig. 480). A gradually increasing jaundice occurs, and in half the cases the gallbladder distends with bile and can be palpated (Courvoisier's Law, p. 465).

In recent years, under the stimulus of Whipple, resection of the head of the pancreas for carcinoma has been frequently done, with various methods of re-establishing continuity of the upper gastrointestinal tract (Fig. 481). The relationship of the head of the pancreas, particularly as to how the uncinate process surrounds the superior mesenteric vessels and portal vein, has made the resection difficult. A distressing finding has been early fixation of the tumor and involvement of the rich lymphatic plexus about the pancreas with metastatic cancer. As a result, the general opinion is that only small, relatively movable tumors should be resected, since the survival rate in other cases so operated upon has not been appreciably longer than when a palliative short-circuiting gastroduodenostomy or gastrojejunostomy was done.

Resection has taught that many patients manage well with a loss of all the external secretion of the pancreas, and the diabetes following a total pancreatectomy is surprisingly mild.

Resection of carcinoma of the body and tail of the pancreas is somewhat easier because it does not involve the duodenum or common

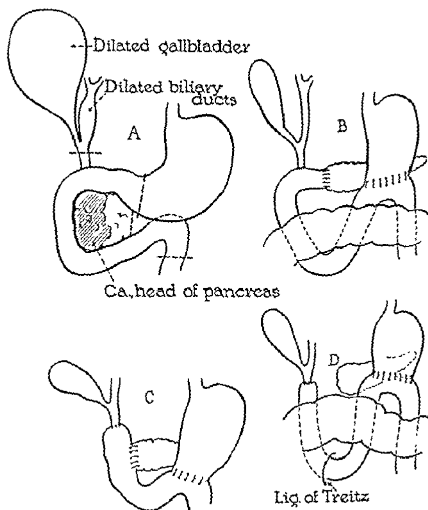


Fig. 481. RESECTION OF THE HEAD OF THE PANCREAS WITH RESTORATIONS OF CONTINUITY.

A, General extent of the excision: lower common duct, gastric antrum, duodenum, and head of the pancreas. *B*, *C* and *D*, Relatively simple methods of restoring upper alimentary tract continuity, with provision for alkaline bile, succus entericus and pancreatic juice (in *B* and *C*) to pass the gastrojejunostomy stoma, thus helping to neutralize acid gastric juice.

bile duct. The best approach is through the gastrocolic (gastrolienal) ligament (Fig. 479). Usually the diagnosis of tumors in these regions is made so late that worth-while resection can seldom be done.

ADENOMA OF THE PANCREAS. Hypoglycemia due to hyperinsulinism arises from a benign adenoma of the islets of Langerhans in 70 per cent of the cases, an islet cell adenomatosis in 2 per cent, local islet cell carcinoma in 20 per cent, and metastasizing islet cell carcinoma in 8 per cent. The diagnosis is based on the triad of Whipple: (1) attacks of nervous or gastrointestinal disturbance coming on in a fasting state; (2) associated hypoglycemia below 50 mg. per cent; and (3) immediate relief with the administration of glucose. Seventy per cent of adenomas are found in the tail of the pancreas, 20 per cent in the head, and 10 per cent in the body. They vary in size from 1 to 15 mm. in diameter, averaging 5 mm.

After the diagnosis of hypoglycemia due to hyperinsulinism has been made the treatment is a thorough exploration of the pancreas for excision of the adenoma. An excellent approach is offered by a transverse upper abdominal incision (Fig. 358, *B*). Division of the gastrocolic ligament allows thorough exploration of the whole pancreas (Fig. 479).

CYSTS OF THE PANCREAS. A pancreatic cyst or pseudocyst usually presents an elastic swelling nearly always in the midepigastrium, but extending farther to the left than to the right. With increase in size the cyst presses forward, but the projection appears at different levels. The progress of cyst growth may be upward and may appear above the lesser curvature of the stomach. In most instances it presses straight forward, flattening out the stomach, and pressing the transverse colon downward until the cyst presents below the greater curvature at the gastrocolic ligame t may burrow

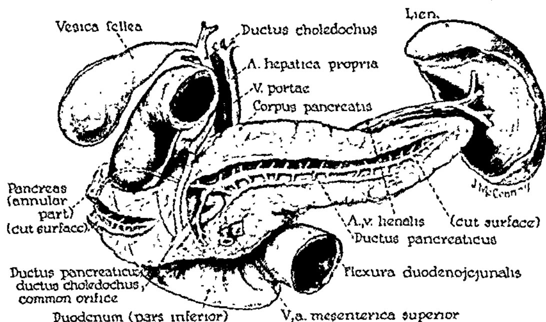


Fig. 482. ANNULAR PANCREAS, SHOWING THE MANNER IN WHICH THE DUODENUM IS SURROUNDED BY A PROLONGATION OF THE HEAD OF THE PANCREAS.

The tributary from the ring of tissue passes to the right over the duodenum, where the tributary is exposed by dissecting away the parenchyma in which it is imbedded; next, *the lesser duct courses posteriorly and to the left; finally it joins the main pancreatic duct* in the head of the pancreas, where the course is indicated by broken lines.

Anterior division of an obstructing annular pancreas is hazardous because it is likely to divide the anterior duct and be followed by a pancreatic fistula. *Some sort of short-circuiting procedure, such as a duodenojejunostomy, is indicated.* (Adapted from Lehman: Ann. Surg., 115: 574–85, 1942.)

downward between the leaves of the transverse mesocolon, or present below the transverse mesocolon.

Cysts of the pancreas frequently require wide exposure because of their general extent. A good approach may be obtained by a long vertical midline incision or a paramedian incision with a left lateral extension (Fig. 357, *E*, *F*, *G*), or a long transverse incision above the umbilicus (Fig. 358, *A*, *B*). A cyst may be extirpated, or its open edges sutured to the deeper layers of the abdominal wound (marsupialization), or anastomosed to the stomach or to the jejunum. The latter procedure seems strange, but the cyst contracts down to a small tract which empties into the bowel.

Duct System of Annular Pancreas. This is shown in Figure 482, and importantly emphasizes that in all adequately studied specimens there is a constant anterior point of origin of the duct which subsequently courses to the right over the duodenum, then posteriorly, then to the left behind the duodenum to enter the head of the pancreas in close relationship to the common duct.

When an annular pancreas obstructs the duodenum, a direct attack by anterior division of the ring is hazardous since it divides the ring duct, a condition frequently followed by a pancreatic fistula. The indirect attack of bypassing the lesion is the best approach, and probably the most common procedure advised to accomplish this is duodenojejunostomy (Fig. 483, *A*). Other methods of treatment are gastrojejunostomy or subtotal gastric resection and gastrojejunostomy.

Congenital malformations are often multiple (Figs. 483, 483A), and annular pancreas is no exception to the rule, other abnormalities being not infrequent.

SPLEEN

Definition and Location. The chief functions of the spleen are (1) the formation of lymphocytes and monocytes; (2) phagocytosis of bacteria, inert particles, white blood cells and probably platelets; (3) destruction of erythrocytes, formation of bilirubin and thus storage of iron; and (4) storage of blood. It is located in the left hypochondrium under cover

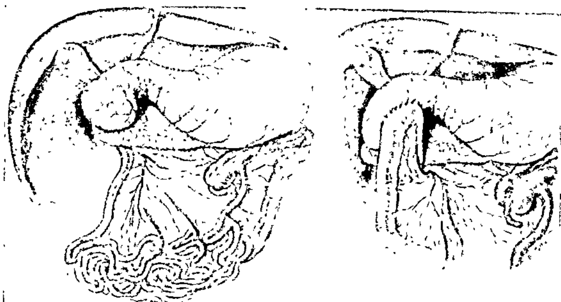


Fig. 483. ANNULAR PANCREAS AND ACCOMPANYING DEVELOPMENTAL MALROTATION; CONDITION AND TREATMENT.

Left, Findings at operation: incomplete rotation of the colon and small intestine; a ring of pancreatic substance surrounding and obstructing the pancreas. The first portion of the duodenum was dilated; distal to the obstruction the colon and intestine were collapsed. *Right*, Surgical alleviation of the duodenal obstruction was accomplished by an isoperistaltic duodenojejunostomy. (From Gross: The Surgery of Infancy and Childhood.)

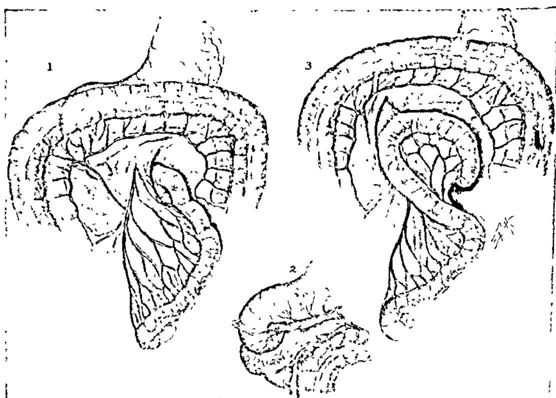


Fig. 483A. ANNULAR PANCREAS; THE USUAL ACCOMPANIMENTS AND A RECOMMENDED METHOD OF THERAPY.

1, Annular pancreas, producing a high degree of duodenal obstruction. 2, Demonstration of the annular pancreas and the obstructed duodenum by reflection of the hepatic flexure of the large intestine. 3, Operative treatment by retrocolic isoperistaltic duodenojejunostomy. The transverse mesocolon has been opened to expose the first part of the duodenum; the jejunum has been brought over against the duodenum for anastomosis. (From Gross: The Surgery of Infancy and Childhood.)

of the ninth, tenth and eleventh ribs, and is the largest of the ductless glands. Deeply concealed beneath the diaphragm and costal arch, it is hidden in great measure by the stomach.

THORACIC PROJECTION OF THE SPLEEN. The surface projection of the spleen is indicated by an oval area confined entirely to the thoracic region. Because of its concealed position, the normal spleen cannot be palpated. The enlarged spleen extends ventrally and lies close beneath the costal arch. With decided enlargement, the organ emerges from beneath the rib cage so that it is possible, especially if the abdominal wall is thin, to palpate the splenic notches of the anterior margin. The direction taken by an enlarging spleen is obliquely downward and mesial, since the phrenicocolic ligament and splenic flexure hinder its enlargement directly downward. This has a certain diagnostic value in differentiating an enlarged spleen from abdominal tumors. It is difficult to outline the spleen by percussion, because the lower border of the left lung intervenes between its upper half and the chest wall, and the stomach is applied against its visceral aspect.

PERITONEAL CONNECTIONS. The layers of the *gastrolienal* (*splenic*) *ligament* separate at the hilus of the spleen. The outer layer invests the gland and then is reflected to the peritoneum over the anterior surface of the left kidney. The deep layer covers the splenic vessels and is continuous with the peritoneum of the floor of the lesser peritoneal sac. Behind and mesial to the spleen, these two layers contain the splenic vessels and form the *pancreaticolienal* (pancreaticosplenic) or *lienorenal ligament*, which passes between the hilum of the spleen and the ventral aspect of the kidney. The inferior extremity of the spleen lies upon, and sometimes is connected with, the *phrenicocolic ligament*, a fold of peritoneum attaching the splenic flexure of the colon to the diaphragm.

DISPLACEMENTS OF THE SPLEEN. In addition to the support the spleen receives from its peritoneal connections, it is maintained in position by the pressure of the surrounding viscera, particularly the left kidney, the splenic flexure of the colon, and the stomach (Figs. 484, 485). Abnormal mobility of the spleen occasionally is encountered as a congenital, but more frequently as an acquired, defect. Mobility is facilitated by stretching or tearing of the splenic ligaments by trauma or by the downward trac-

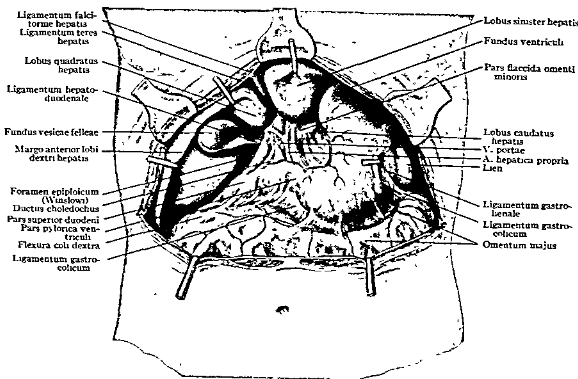


Fig. 484. SUPRAMESOCOLIC VISCERA, WITH SPECIAL REFERENCE TO THE LOCATION OF THE SPLEEN.

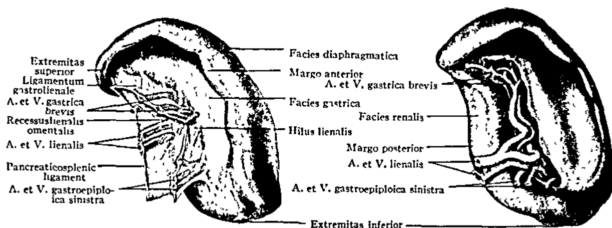


Fig. 485. SPLEEN, VIEWED FROM THE ANTEROMEDIAL ASPECT.

Left, The organ with peritoneal connections retained. *Right*, The spleen with serous and subserous layers removed in order to expose the arteries and veins.

tion of the organ when enlarged. The supporting ligaments may be stretched to a remarkable degree, and the spleen may come to rest in the abdomen or pelvis, in which case it is known as a *prolapsed*, *ectopic* or *wandering spleen*.

When the pedicle is elongated greatly and permits the spleen to float about the abdominal cavity upon the coils of intestine, it may rotate on its horizontal axis, resulting in torsion of the pedicle. The organ may become fixed in an abnormal position by adhesions forming between it and the parietal peritoneum or the viscera.

VESSELS OF THE SPLEEN. The arterial supply of the spleen comes from the large LIENAL (SPLENIC) ARTERY, which runs a generally transverse course from right to left along the superior margin of the pancreas (Figs. 407, 485). Near the hilus, and within the lienorenal ligament, the artery divides into numerous branches, chief of which are the superior polar, left gastro-epiploic, superior terminal and inferior terminal arteries. The well developed *superior polar artery* arises some distance from the hilus and, before entering the spleen, gives off the short gastric arteries to the stomach. The *left gastro-epiploic artery* passes along the inferior pole of the spleen to supply part of the greater curvature of the stomach and the great omentum (Figs. 467, *b*; 478).

The *superior* and *inferior terminal arteries* resolve into secondary branches which penetrate the splenic parenchyma at the hilus along an irregularly disposed line drawn from one splenic pole to the other. The ultimate branches are end-vessels, each of which supplies a wedge-shaped area, the base of which is directed toward the periphery of the spleen. If one of these vessels is plugged, no blood passes directly into the area it supplies, and an *infarct* results. The central portion of the infarcted area is pale in color, but its outlying parts are stained deeply with blood which has diffused into it from the surrounding avascular zones. Infarction is common in heart disease, in which emboli may be detached from the valves of the left side of the heart and carried into the aortic branches.

The SPLENIC VEIN begins in several large branches leaving the hilum of the spleen. It pursues a much straighter course than the artery, and runs dorsal to the pancreas from left to right, joining with the superior mesenteric vein to form the portal vein (*Fig. 436*). The junction occurs behind the head of the pancreas and ventral to the inferior vena cava.

The LYMPHATICS of the splenic capsule enter the lymph glands of the hilus, which, in turn, drain to the nodes along the splenic artery and into the celiac glands (Fig. 408).

Surgical Considerations

Removal of the spleen is the only operation done upon this organ, and it is difficult to be sure of the value of the operation in many conditions. In the following, however, splenectomy is considered to be of decided value: traumatic and nontraumatic rupture of the spleen, ptosis and torsion of the spleen, congenital hemolytic jaundice, thrombocytopenic purpura, cysts and hemangiomas of the spleen, tumors of the spleen, abscess of the spleen, malarial spleen, chronic splenic neutropenia,

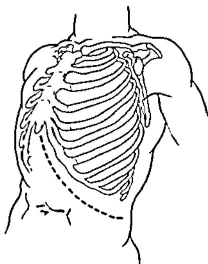


Fig. 486. CURVED SUBCOSTAL INCISION RECOMMENDED FOR SPLENECTOMY IN CHILDREN.
(From Glenn, Cornell, Smith and Schulman: Surg., Gynec. & Obst., 99: 689–702, 1954.)

congestive splenomegaly, splenic anemia, selected cases of Banti's syndrome, schistosomiasis, and with total or nearly total gastrectomy for extensive carcinoma of the stomach.

SPLENECTOMY. Good access to the spleen can be obtained by a vertical midline or paramedian incision with a lateral extension (Fig. 357, *E*, *F*, *G*), or through a transverse incision (Fig. 358, *A*). Really excellent exposure is possible through Carter's combined abdominothoracic incision (Fig. 487). For children, Glenn and associates are loath to use the latter because of the considerable trauma and possible morbidity from complications associated with the combined approach. For this group they prefer a left upper quadrant subcostal incision (Fig. 486). It is advantageous to ligate the splenic artery first. Venous return then milks the spleen of several hundred cubic centimeters of blood and reduces its size by 25 to 35 per cent. Also, bleeding from torn veins in the splenic hilum is less troublesome. The best approach to the splenic artery lying along the upper border of the pancreas is through the gastrocolic ligament (Fig. 479). When few adhesions make delivery of the spleen easy, the artery and veins can be divided close to the hilum.

ACCESSORY SPLEENS. Curtis and his associates have emphasized the importance of searching for accessory spleens during splenectomy



Fig. 487. EXCELLENT EXPOSURE OF THE SPLEEN THROUGH CARTER'S ABDOMINOTHORACIC INCISION.

Control of the splenic blood supply is easily obtained by ligating the artery as it courses along the upper border of the pancreas (Fig. 478). It is also simple in many instances to divide the splenocolic and splenorenal ligaments, separate the adhesions from the diaphragm, free the posterior aspect of the pedicle from the pancreas, divide the gastrosplenic ligament, and then individually ligate the splenic arteries and veins in the hilum. This procedure is well suited for splenectomy and preservation of a good length of splenic vein for splenorenal anastomosis. (From Carter: Surg., Gynec. & Obst., 84: 1019–28, 1947.)

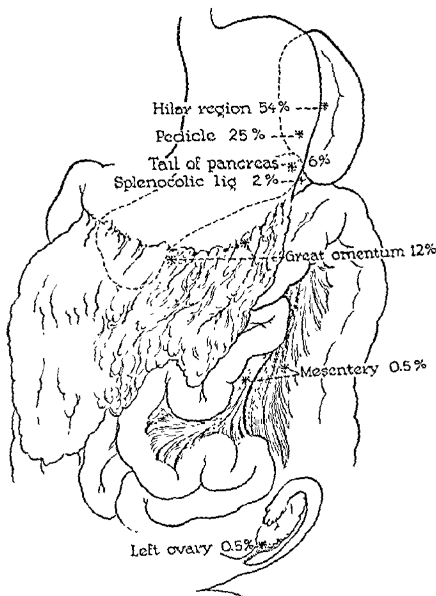


Fig. 488. POSITIONS OF ACCESSORY SPLEENS FOUND AT FIFTY-SIX OPERATIONS. FIGURES INDICATE PERCENTAGE OCCURRENCE.

In 85 per cent of the cases the accessory spleen was single, that is, in but one location. Eight instances of double location occurred, distributed as follows: in 4 cases at the splenic hilus and in the omentum; in 2 instances at the hilus and pedicle; in 2, at the hilus and in the splenicocolic ligament. (From Curtis and Movitz: Ann. Surg., 123: 276–98, 1946.)

for congenital hemolytic icterus and primary thrombocytopenic purpura in order to prevent recurrence of symptoms. The surgeon should be aware of the positions in which such accessory spleens are likely to occur (Fig. 488).

SPLENORENAL SHUNT FOR RELIEF OF PORTAL HYPERTENSION. This procedure (Fig. 489) is one of the surgical methods for the relief of increased pressure in the portal venous system. The obstruction is produced by a number of causes: periportal cirrhosis of the liver (Laennec type), congestive splenomegaly (Banti's syndrome), thrombosis of the splenic vein, cavernous transformation or stenosis of the portal vein, and schistosomiasis mansoni. The late symptoms are ascites, loss of weight, hemorrhages from the skin and gastrointestinal tract (commonly due to esophageal varices), periumbilical venous enlargement, and jaundice.

Anastomosing the splenic vein to the renal vein forms a fistulous channel for blood to pass from the portal system to the general venous system and thus reduce the portal hypertension (Fig. 489).

BLEEDING ESOPHAGEAL VARICES AFTER SPLENECTOMY. It is not generally accepted that for a patient with extrahepatic portal obstruc-

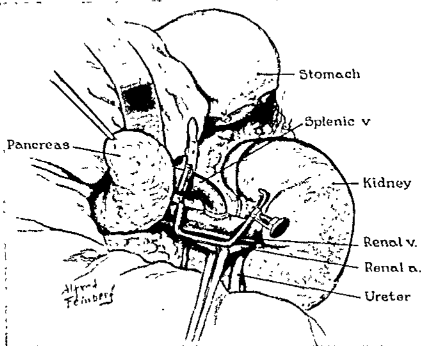


Fig. 489. END-TO-SIDE SPLENORENAL ANASTOMOSIS FOR PORTAL HYPERTENSION.

Excellent exposure for this operation is obtained by a left thoracoabdominal approach through the bed of the resected tenth rib. (From Blakemore: South. Surgeon, 16: 386–402, 1950)

tion plans for a splenectomy alone should never be made, but the surgeon should be prepared to carry out a splenorenal anastomosis at the same time if the splenic vein is patent and sufficiently large. Hallenbeck and Shocket* list the factors leading to this recommendation as follows: (1) Addition of splenorenal anastomosis to splenectomy for extrahepatic portal obstruction is rational; (2) though final appraisal of results of shunting versus results of splenectomy alone is not yet possible, data to date favor shunting; and (3) in those patients with normal livers, addition of the shunt has not increased the operative mortality rate as compared with that following splenectomy alone.

For those patients having extrahepatic portal obstruction on whom a splenectomy has been done and bleeding from esophageal varices has recurred, Hallenbeck and Shocket believe that a search should be made to determine whether or not a satisfactory large shunt is feasible between some branch of the portal and the caval systems. They make at laparotomy a short, nearly transverse incision below and to the right of the umbilicus, which can be extended to form a right thoracoabdominal incision if the findings warrant it. The following steps are taken: (1) The abdomen is explored in the usual manner; (2) the liver is examined, and a biopsy specimen is taken; (3) the region of the portal vein is palpated in the search for veins which may be accessible for anastomosis to the vena cava, and the presence or absence of any other large veins which might serve is noted; and (4) the superior mesenteric vein is cannulated with polyethylene tubing through a branch in the mesentery of the jejunum so that portal pressure can be measured and portal circulation can be investigated by injecting 40 to 50 ml. of 70 per cent sodium acetrizoate (Urokon) and taking a roentgenogram. The presence of hepatofugal flow of blood in the portal system coupled with elevated portal pressure confirms the diagnosis of obstruction to the portal system. If a shunt is not feasible, some other procedure is undertaken, usually at the same operation. Recently Hallenbeck and Shocket have been evaluating transesophageal ligation of the varices performed through a left thoracotomy incision as practiced by Crile, being attracted to it by its relative simplicity and by the fact that it avoids the serious sequelae which sometimes follow esophagogastric resection. Of sixteen postsplenectomy

* Arch. Surg.: 71: 581–7, 1955.



Fig. 490. LARGE VARICES OF THE ESOPHAGUS IN THEIR MOST COMMON POSITION IMMEDIATELY ABOVE THE DIAPHRAGM.

(From Hallenbeck and Shocket: Arch. Surg., 71: 581–7, 1955.)

bleeders, seven were able to have some form of portacaval anastomosis, and two subsequently had episodes of recurrent bleeding. Nine patients were unsuitable for shunting and underwent transesophageal ligation of the varices. An example of the operative finding is presented in Figure 490.

LIGATION OF THE SPLENIC ARTERY. The operation of splenorenal shunt or portacaval anastomosis for portal hypertension* is of considerable magnitude and often beyond the capacity of patients seriously ill with this disease. Since the spleen is the source of 40 per cent of the blood to the portal circulation, a ligation of the splenic artery (Fig. 479) is occasionally done as a lesser procedure in the attempt to relieve portal hypertension.

INFRAMESOCOLIC VISCERA

The inframescocolic viscera include the bulk of the small intestine (jejuno-ileum), the ileocecal segment, and the ascending, transverse and descending portions of the colon.

JEJUNUM AND ILEUM (JEJUNO-ILEUM)

DEFINITION AND BOUNDARIES. The small bowel, extending from the duodenojejunal flexure to the cecum, is freely movable. The upper two fifths is *jejunum* and the lower three fifths *ileum*, but there is no morphologic demarcation between the two segments. The small bowel in the adult averages 22 feet in length. Its caliber is not uniform, but diminishes from above downward, being narrowest at the termination.

POSITION AND ARRANGEMENT. The jejuno-ileum, contained within a limited space, of necessity is coiled in a complicated fashion. It is connected to the posterior abdominal wall by a fold of peritoneum, the mesentery proper, which allows great range of mobility. For the most part the jejuno-ileum is contained in that part of the abdomen which lies below the subcostal plane, and in the pelvis. The coils are related in front to the anterior abdominal wall and the greater omentum, which, as a rule, is spread over them. They are hemmed in by the large bowel, and related behind to the posterior abdominal wall and retroperitoneal structures.

The position of the intestinal coils in the abdomen cannot be predetermined accurately. Several anatomic facts suggest that the largest part of the adult small intestine occupies the left half of the abdomen. These facts are the natural position with reference to the mesenteric insertion, the elevated position of the left colic flexure, and the direct communication between the left half of the abdominal cavity and the pelvis.

Like its mesenteric attachment, the small intestine is disposed in an irregularly curved line from the upper left to the lower right quadrant. The uppermost portion lies in the left hypochondrium, reaching the left colic flexure, and is covered, to a degree, by the transverse colon and mesocolon. The succeeding loops lie in the right abdominal cavity, whence they extend into the left iliac fossa and then again to the right to fill the pelvis. From the pelvis a terminal loop passes upward into the right iliac fossa to join the large bowel. In pelvic peritonitis of tubal, ovarian or appendiceal origin, *the pelvic loops of ileum* become involved and adherent. Pelvic coils are most liable to strangulation by obstructive bands from an adhesive peritonitis.

MESENTERY OF THE JEJUNO-ILEUM. A mesentery suspends the jejuno-ileum from the posterior abdominal wall and contains the neurovascular system of the intestines. Its parietal attachment or root extends from the left side of the second lumbar vertebra downward to

* Blain and Blain: Ann. Surg., 131: 92–9, 1950.



Fig. 491. MESENTERIC RUFFLE, SHOWING THE GROUPS AND DISPOSITION OF THE COILS OF THE JEJUNO-ILEUM.

A, Proximal coils of jejunum; *B*, more terminal groups of jejunum; *C*, upper ileum; *D*, midileum; *E*, terminal coils of ileum. Note how pelvic peritonitis from tubal ovarian or appendiceal inflammation, or operations upon these structures, may result in adhesions to terminal loops of ileum. Small intestine obstructions from adhesions are most common in this region. (From Kelly, Hurdon: Vermiform Appendix.)

the right, across the aorta and inferior vena cava, to the right sacroiliac joint, a distance of about 15 cm. (Fig. 491). It crosses the ventral surface of the transverse stage of the duodenum, where it contains between its layers the superior mesenteric vessels, the lymphatics and the nerves. Removal of a cyst or solid tumor of the mesentery endangers the terminal blood supply of the intestines and exposes them to gangrene. The mesentery, in traversing the inframesocolic compartment, converts it into two spaces, that to the right being much smaller and terminating in the right iliac fossa, and that to the left being much the larger and passing uninterruptedly into the true pelvis.

The distance between the intestinal and parietal mesenteric attachments is insignificant at the upper and lower extremities, and is greatest where the attachment crosses the spine. The depth of the mesentery, as a rule, does not exceed 20 to 25 cm. The length, in many instances, permits the descent of the small bowel into the sac of an inguinal or femoral hernia. When the mesentery seems unusually long, it probably is not actually lengthened, but is able to slide downward on a loose extraperitoneal attachment.

Fat deposition is marked along the mesenteric root, and diminishes toward the intestinal attachment. The amount of fat is greater in the distal end of the mesentery than in the proximal. A group of infected lymph nodes in the mesentery may become adherent to an adjoining loop of small bowel and cause a mechanical intestinal obstruction. An acute terminal *mesenteric lymphadenitis* frequently is indistinguishable from acute appendicitis. Near the duodenojejunal flexure can be seen semitranslucent areas of peritoneum, separated from one another by branches of the superior mesenteric vessels. These areas or "windows" become more obscure as the jejunum is traced distally, until, in the distal part of the ileum, they scarcely can be distinguished because of the deposition of fat near and about the bowel. An examination of the mesentery, therefore, may determine whether a loop of small intestine drawn through an abdominal wound belongs to a proximal or a distal segment.

Failure of the root of the mesentery to fuse over its entire extent with the posteriorparietal peritoneum allows a pocket to be formed between it and the peritoneum which may form the sac of an intraperitoneal hernia (*mesenteric-poarietal hernia of Waldeyer*, Fig. 492).

STRUCTURE. Beneath the serosa the small

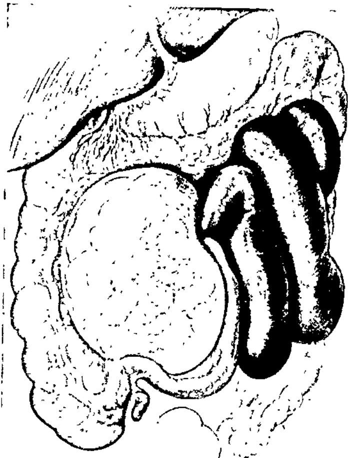


Fig. 492. MESENTERICOPARIETAL HERNIA OF WALDEYER.
(From Foote: California & West. Med.)

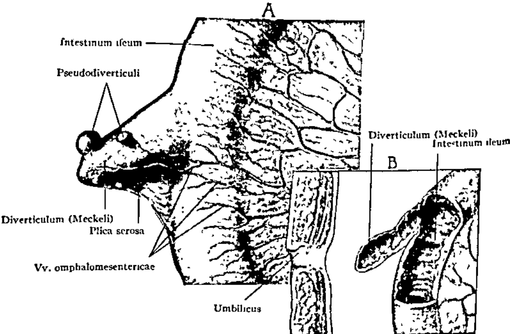


Fig. 493. ILEAL DIVERTICULUM (OF MECKEL).
A, The diverticulum along which lie the omphalo(vitello)-intestinal vessels; *B*, a section removed from the ileum and from the diverticulum. (After Cullen).

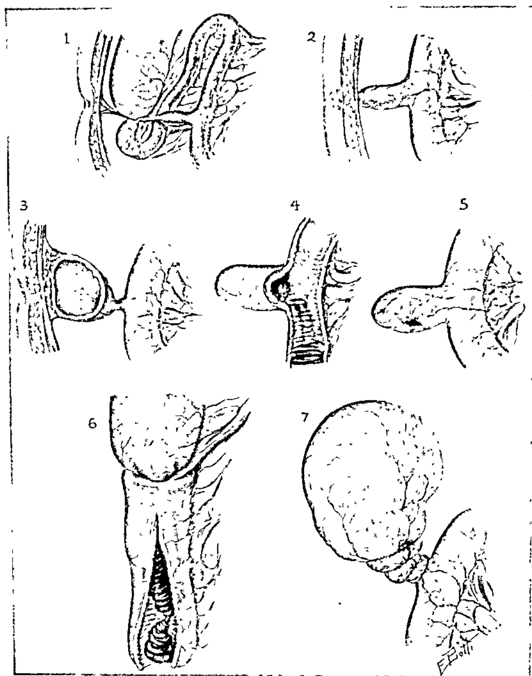


Fig. 494. WAYS IN WHICH MECKEL'S DIVERTICULUM GAVE RISE TO PATHOLOGICAL LESIONS IN 149 CASES.

1, Intestinal obstruction caused by a band passing from the diverticulum to the inner aspect of the umbilicus; 8 cases. 2, Fistula at the umbilicus; 11 cases 3, Cyst internal to the umbilicus; 1 case. 4, Ulceration in the diverticulum giving rise to intestinal hemorrhage; 50 cases. 5, Diverticulitis, with or without perforation; 18 cases. 6, Intussusception with the diverticulum acting as the leading point; 28 cases. 7, Torsion and infarction of the diverticulum; 4 cases. In 29 additional patients there was abdominal pain, assumedly originating from Meckel's diverticulum, but without demonstrable pathology therein. (From Gross: The Surgery of Infancy and Childhood.)

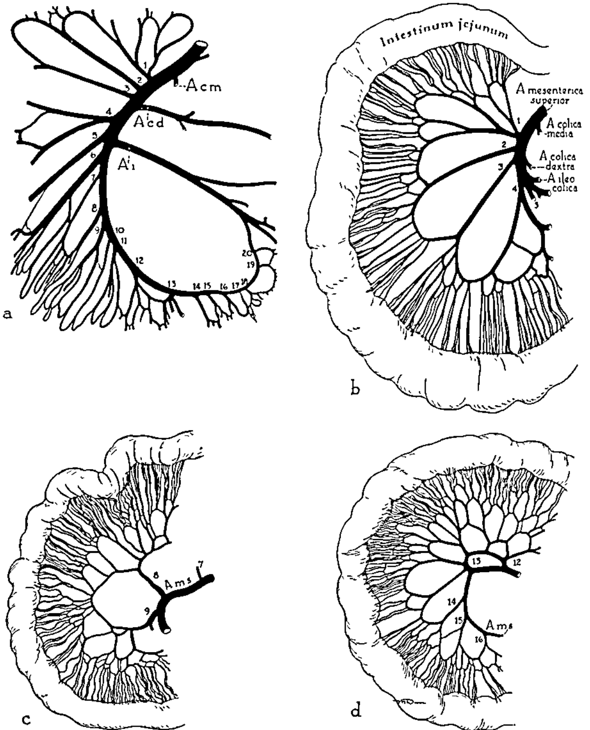


Fig. 495. ARTERIAL SUPPLY OF THE SMALL INTESTINE; FROM A SINGLE SPECIMEN.

a, Superior mesenteric artery with its intestinal branches (numbered 1 to 20). Abbreviations: *A.c.m.*, arteria colica med *A c.d.*, a. colica dextra; *A.i.*, a. ileocolica. *b*, Proximal segment (duodenal extremity), with first 4 intestinal arteries, th arcades and straight branches. *c*, Intermediate segment, with the eighth and ninth intestinal branches; the arcades form more complex pattern, and their straight arteries are shorter. *d*, Distal segment (near the terminal ileum), including t twelfth through the sixteenth intestinal arteries; lunettes to the fourth order are formed by the arcades; the straight arter are of minimal length. (From Beaton and Anson: Quart. Bull., Northwestern Univ. M. School, 16: 114–22, 1942.)

bowel has a strong muscle coat, which consists of an outer longitudinal and an inner circular layer. Plicae circulares (valvulae conniventes), ridges of the thick mucosa which begin in the descending duodenum, are numerous in the proximal jejunum. By grasping the jejunum between the thumb and finger, these folds can be felt through the wall of the gut; their absence in the distal ileum serves to distinguish the proximal from the distal segment. In the ileum, but not in the jejunum, are numerous aggregated lymph nodules which vary in length from 2 to 10 cm. They form granular patches (Peyer's patches) in the mucosa along the antimesenteric border.

Abnormalities of the Omphalo (Vitello)-intestinal Duct. In the early human embryo the convexity of the umbilical loop of the primitive gut communicates freely with the yolk sac by the *omphalo(vitello)-intestinal* duct. As development proceeds, the duct normally becomes occluded and later disappears entirely. All or any part of the duct may persist (Fig. 493). With the *duct completely permeable*, a *congenital fecal fistula* at the umbilicus results. The duct may be several inches in length, or so short that the ileum itself appears to open on the surface.

In the latter instance the mesenteric wall of the bowel may prolapse through the opening and produce intestinal obstruction. Persistence of the intra-embryonic duct is to be differentiated from *persistence* of a *small part* of the *extra-embryonic duct*, which causes a mucous discharge. Probing of the duct indicates which condition is present.

With the *duct partially persistent*, only that part of the duct immediately deep to the umbilicus may remain patent, and a *cyst opening on the umbilicus* occur; or only the middle portion may persist and a *cyst of the duct* occur (Fig. 494). A free *blind diverticulum attached to the ileum* (*Meckel's diverticulum*) is the commonest anomaly. It usually occurs within a

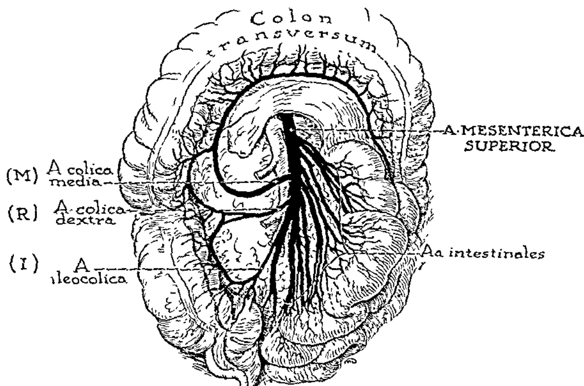
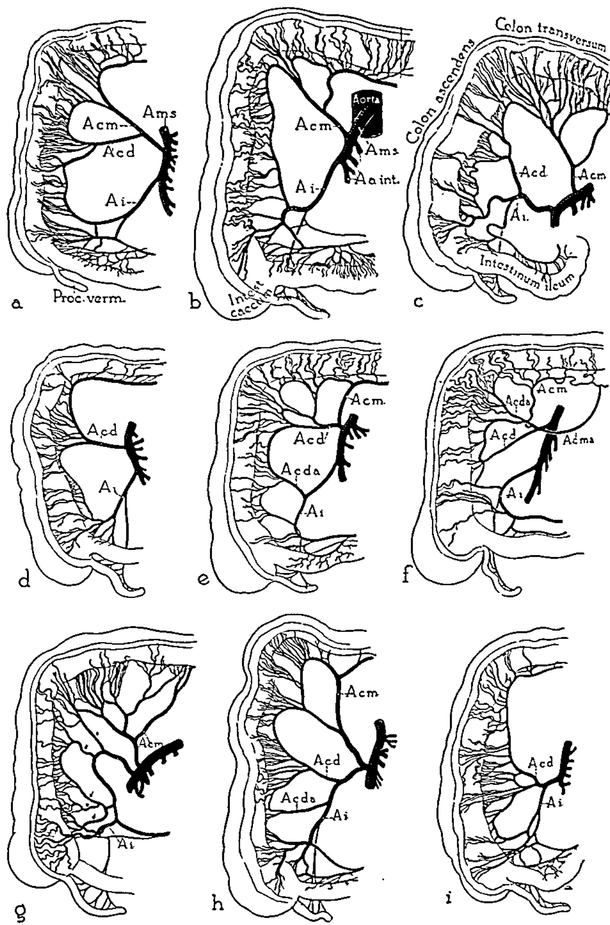


Fig. 496. COLIC BRANCHES OF THE SUPERIOR MESENTERIC ARTERY.

The arteries revealed by lifting the transverse colon and drawing the coils of small intestine to the subject's left have been exposed by removing the parietal peritoneum and the layers of mesentery of the jejuno-ileum.

Here the 3 vessels of supply to the ascending and transverse segments of the colon arise as separate branches of the superior mesenteric artery; they are the ileocolic (at *I*), the right colic (*R*) and the middle colic (*M*). This pattern occurred in approximately 25 per cent of 400 specimens studied; specimens represented by this figure and those represented by *a* and *b* of the succeeding series of types made up approximately 60 per cent of the total number (400) examined. (From Sonneland, Beaton and Anson: Surg., Gynec. & Obst., 106: 385-98, 1958.)


Ams
Acm
Acd
Ai
Proc. verm.
a
Aorta
Acm
Ams
Aa int.
Ai
Intest. caecum
b
Colon transversum
Colon ascendens
Acd
Acm
Ai.
Intestinum ileum
c
Acd
Ai
d
Acm.
Acd'
Acda
Ai
e
Acm
Acda
Acd
Acma
Ai
f
Acm
Ai
g
Acm
Acd
Acda
Ai
h
Acd
Ai
i

meter of the terminal ileum, and may or may not have a mesentery. There are various ways in which the diverticulum may be the source of pathological lesions (Fig. 494); among these are intestinal obstruction, formation of fistula or cyst, ulceration, hemorrhage, diverticulitis, intussusception and torsion with infarction (Gross). Occasionally the *vitello-intestinal vessels may persist* with no trace of the diverticulum. In inflammation the free diverticulum *may acquire adhesions to any neighboring* structure and cause intestinal obstruction.

VESSELS AND NERVES. The arteries supplying the jejuno-ileum spring from the left aspect of the *superior mesenteric artery*, which arises from the aorta about 2 cm. below the origin of the celiac trunk and behind the head of the pancreas. This artery leaves the deep surface of the gland at the incisura and enters the root of the mesentery. As it descends toward the right iliac fossa, it describes a curve with a convexity directed to the left. It terminates at the mesial aspect of the cecum by anastomosing with one of its own branches, the ileocolic artery.

Close to the origin of the trunk, the inferior pancreaticoduodenal artery is given off. It runs to the right between the head of the pancreas and the duodenum, supplying both these structures and anastomosing with the superior pancreaticoduodenal artery (p. 488). The intestinal arteries break up into a series of arcades more complex in the ileum than in the jejunum (Fig. 495). From the convexities of the terminal arcades, small parallel vessels (vasae rectae) pass to the mesenteric border of the bowel and bifurcate. *This difference between the jejunum and ileum* may be used by the operating surgeon to tell whether a given loop of small intestine is of the upper or lower region: The jejunum has one or two arterial arcades with long, 3 to 4 cm., parallel end vessels going to the gut, while the ileum has two to three arterial arcades with short, 1 to 3 cm., terminal vessels. Compared to the ileum, the jejunum is somewhat larger, is a little crinkly in appearance, and often a bit whitish because of chyle in its lymphatics. There is less fat in the jejunal mesentery than in the ileal. In the intestinal wall the vessels run parallel to the circular muscle coat, traversing successively the serous, muscle and submucous layers. Injury to the mesentery containing these vessels is likely to cause gangrene in the part of the bowel they supply, because the anastomoses of the superior mesenteric artery with the celiac and inferior mesenteric arteries are not adequate to re-establish circulation if a large trunk or one *of its main branches is destroyed. In sectioning* the bowel for anastomosis it is advisable to remove less of the mesenteric than of the antimesenteric border in order that the cut margin may have a good blood supply.

The middle colic, right colic and ileocolic arteries are highly variable in pattern (Figs. 496, 497).

The *superior mesenteric vein* returns blood from the small intestine and from the ascending and transverse colon. Behind the neck of the pancreas it unites with the splenic vein to form the portal vein (p. 447). The superior mesenteric vein may be the site of a thrombosing phlebitis, terminating in intestinal venous engorgement, gangrene, intestinal obstruction, and peritonitis.

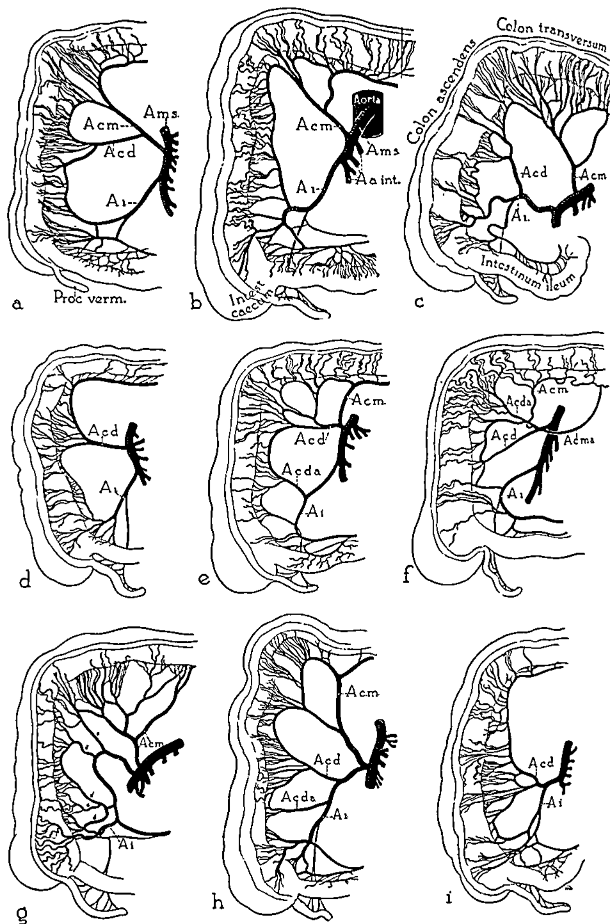
The *lymphatics* originate in the central lacteals of the mucosal villi and are directed to rich plexuses in the submucous coats. The plexuses join the superior mesenteric lymph nodes within the mesentery where they lie in close relation to the arterial arches. This intramesenteric group of glands may be infected with tuberculosis directly from the alimentary tract. Tuberculous infection, spreading along the lymphatics from an ulcerated aggregated lymph nodule (Peyer's patch) may cause a stricture of the bowel. Acute miliary tuberculosis commonly arises in this way in consequence of the large numbers of bacilli passing from the lymphatics into the lymphatic duct and thence into the general circulation. Aggregated lymph nodules are most numerous in the terminal ileum, which is consequently the most common site for tuberculous stricture.

The *nerve supply* of the small intestine is

Fig. 497. COLIC BRANCHES. TYPES OF BRANCHING OF THE SUPERIOR MESENTERIC ARTERY (CONTINUED).

Patterns arranged generally in the order of decreasing frequency, as they were encountered in a study of 400 specimens. Separate origin of the 3 arteries of supply to the ascending and transverse portions of the colon occurs most frequently; on the contrary, combined origin occurs rarely.

Abbreviations: *Aa. int., arteriae intestinale* (intestinal arteries); *A.c.d., arteria colica dextra* (right colic artery); *A.c.d.a., arteria colica dextra accessoria* (accessory right colic artery); *A c.m, arteria colica media* (middle colic artery); *A.c.m.a., arteria colica media accessoria* (accessory middle colic artery); *A. ileocolica* (ileocolic artery); *Proc. verm., processus vermiformis* (vermiform process, or appendix). (From Sonneland, Beaton and Anson: Surg., Gynec. & Obst., 106:385–98, 1958.)



Acm
Ams.
Acd
Ai
Proc verm.
a
Aorta
Acm
Ams
Aa int.
Ai
Intest caecum
b
Colon ascendens
Colon transversum
Acd
Acm
Ai
Intestinum ileum
c
Acd
Ai
d
Acm
Acd'
Acda
Ai
e
Acda
Acm
Acd
Acma
Ai
f
Acm
Ai
g
Acm
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Acda
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h
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i

by continuous gastroduodenal suction through an intranasal Wangensteen or Miller-Abbott tube.

An *ileostomy* is an enterostomy performed usually in the right lower quadrant to shunt the fecal stream away from the colon. The colon is thus put at rest, generally in the hope that a severe inflammatory process such as chronic ulcerative colitis will improve. Either a double-barreled or single-barreled opening is made. Unfortunately, the continuity of the bowel is seldom restored, the colon inflammation almost always persisting and ultimately requiring a colectomy.

The greatest problem in an ileostomy is to keep the almost constantly running intestinal juices from digesting the surrounding skin. The best prevention is a rubber collecting bag glued to the skin immediately around the mucosal opening.

A *jejunostomy* is an enterostomy commonly done to administer nourishing fluids into the intestines when the stomach cannot be used, usually because of advanced malignancy.

Intestinal Resection. The common indications for removal of portions of the small bowel are gangrene, tumors or chronic inflammation. Gangrene is always due to a compression, as by an adhesive band; to intussusception or strangulating hernia; to a twist, as in volvulus; or to thrombosis of the vessels supplying a segment of bowel. Tumors of the small intestine are relatively rare, only 3 per cent of bowel tumors being there, and 97 per cent in the colon. Chronic infections benefitting by resection are tuberculosis and regional ileitis. Patients have been reported living satisfactorily after two-thirds of the small bowel have been removed.

The technique of small intestinal resection is relatively simple and depends upon approximating the two peritoneal surfaces, which then

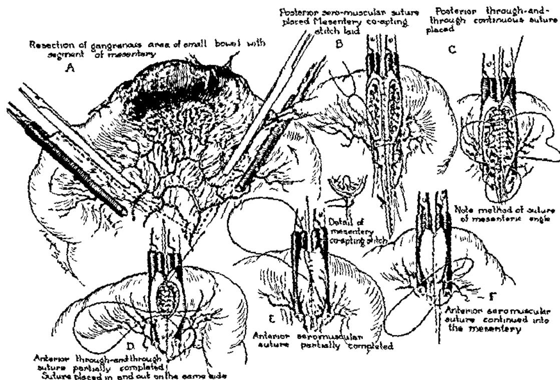


Fig. 499. OPEN METHOD OF SMALL BOWEL ANASTOMOSIS.

To lessen the crushing effect, the rubber-shod clamps might well be placed farther away from the line of anastomosis than shown in this illustration. In fact, they may safely be dispensed with entirely. If fecal contamination is feared during the anastomosis, a single suture ligature may be passed through the mesentery adjacent to the bowel at a point 6 to 10 cm. from the cut ends, and then tied loosely, just enough to stop the fecal stream. There will be minimal interference with the blood supply (Gambee and Nadal).

This illustration shows an older, but still useful, method of anastomosis. An end-to-end approximation with less obstructive infolding of the bowel can be done with a single layer of submucosal interrupted silk or cotton sutures.

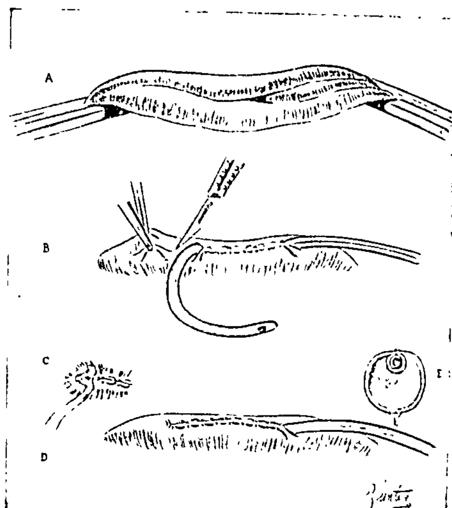


Fig. 498. TECHNIQUE OF ENTEROSTOMY.

A, Rubber-shod clamps holding a selected loop of bowel at both ends. If distended, the loop should be emptied by stripping or evacuation of its contents. *B*, No. 14 French catheter laid upon the bowel and tunneled in by a few interrupted submucosal mattress sutures of fine silk. A pointed knife makes a puncture wound at the end of the tunnel through which the catheter is inserted into the lumen. *C*, Seromuscular stitches close the bowel over the site of the catheter insertion. *D*, Completion of the enterostomy. *E*, Cross section of the bowel lumen and peritoneal tunnel. When the catheter is withdrawn, the long tract will close spontaneously. (From Wangensteen: Intestinal Obstruction. Springfield, Ill., Charles C Thomas.)

derived from the celiac plexus of the sympathetic system and from the vagus. Referred pain in connection with a lesion of the small bowel is experienced in areas supplied by the ninth, tenth and eleventh thoracic nerves. Clinically, the pain usually is about the umbilical region, and only occasionally spreads to the lumbar region and back.

Surgical Considerations

INTESTINAL INJURIES. Of all the abdominal viscera, the small bowel is exposed most to injury, but the elasticity and ease with which the coils glide over one another and elude pressure serve to protect it.

A minute puncture wound of the bowel may not lead to extravasation of intestinal contents, since the muscle coats may contract so as to close the opening. If the rent is large and mucosa is everted into the wound, spontaneous closure becomes difficult. The bowel may be injured to the point of severance by traumatic compression against the spinal column or sacral promontory. Intestinal perforation should be closed surgically at the earliest possible moment.

ENTEROSTOMY. An enterostomy is the formation of an artificial fistulous communication between the lumen of some part of the small bowel and the surface of the skin (Fig. 498). The procedure is used as an inlet to furnish nourishment, and only occasionally as a means of emptying the bowel in intestinal obstruction. The latter use has been largely obviated

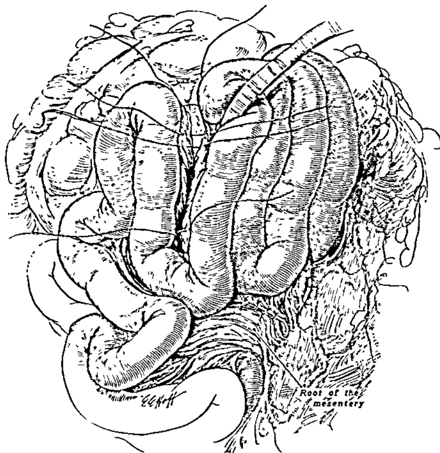


Fig. 501. THE NOBLE PLICATION OPERATION.

A method of controlling the folds of the small intestine in cases of recurring intestinal obstruction from adhesions. The plicated loops of bowel are about 7 to 8 inches in length, and in severe cases the entire jejunum and ileum must be so approximated. (From Barron and Fallis: Arch. Surg., 71: 518–22, 1955.)

medial and posterior aspects of the cecal segment.

The large intestine differs from the small intestine in the following particulars: it is not surrounded entirely by its longitudinal muscle coat, but derives from it three narrow bands, the taeniae coli, which are clearly visible through the serosa; its wall is thinner, chiefly because of the deficiency in the longitudinal coat; it has epiploic appendices, small peritoneal sacs filled with fat, which are attached mainly to the transverse and sigmoid portions of the colon.

ANATOMIC SUMMARY OF THE CECUM. The cecum comprises that part of the large bowel located below a transverse line passing just above the ileocecal valve. It is about 6 cm. long and 7 cm. wide, and lies normally upon the iliopsoas muscle in the right iliac fossa in the angle formed by the flare of the ilium and the anterior abdominal wall. When filled with gas and fluid, the cecum reaches the mesial border of the psoas muscle and may form a palpable, and sometimes visible, tumor mass. Manipulation of this tumor often produces gurgling. In complete obstruction of the transverse or descending colon or sigmoid the cecum commonly shows the most distention, and may rupture. Certain factors cause the cecum, rather than other parts of the colon, to give way. The cecum is the thinnest-walled part of the colon. Second, carcinoma at the splenic flexure, for example, produces partial obstruction for some time. Chronic distention and hypertrophy of the proximal large bowel occur. The bowel wall hypertrophy gradually diminishes toward the cecum, which is thinner and relatively weaker. For cecal perforation to occur, the ileocecal valve must be closed to localize distention at the cecum. Incompetence of the ileocecal valve makes diastasic perforation of the cecum rare (Saeltzer and Rhodes).

adhere quickly and securely. End-to-end anastomosis best approaches normal continuity and is preferred to side-to-side or end-to-side restorations. Some surgeons prefer the open method of anastomosis (Fig. 499), and others use the closed or aseptic procedure (Fig. 500).

THE NOBLE PLICATION OPERATION. This procedure was first described by Noble* in 1937 as a method of controlling the folds of the small intestines in cases of recurring intestinal obstruction from adhesions. All too frequently simple lysis of severe adhesions is followed by only temporary relief, and some surgeons now feel that the plication method (Fig. 501) is of definite value in lessening the chances of further obstruction.

ILEOCECAL-APPENDICEAL REGION

The few terminal centimeters of the ileum, the cecum and the appendix may be grouped into an important surgical anatomic composite.

* Am. J. Surg., 35: 41–4, 1937.

During early development the large intestine is a tube of uniform dimensions, and its cecal segment presents no distinguishing features. The lower part of the cecal segment lags in growth, while the upper part keeps pace with the growth of the colon (Fig. 502). As the difference in size becomes greater, the lower, tapering extremity becomes the vermiform appendix; the roomy part above it, the cecum. At birth the cecum has a conical shape, a smooth external appearance, and a well marked curve in its long axis with its concavity directed upward and inward, so that the tip of the appendix comes into close proximity with the end of the ileum. By the third year longitudinal bands, or taeniae, with sacculi between them, are developed. The sacculus between the anterior and lateral bands develops out of proportion to the others and causes the cecum to assume a globoid form. This large sacculus forms the most dependent part, or fundus, and the greater part of the anterior wall of the cecum. The appendix is attached, then, to the

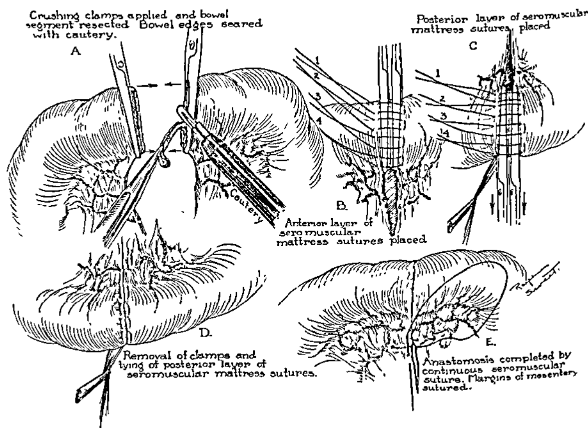


Fig. 500. CLOSED OR ASEPTIC METHOD OF SMALL BOWEL ANASTOMOSIS.

In using 2 layers of sutures there is always the danger of turning in too much tissue and thus obstructing the lumen. A concern about the closed method is that the vascular injury produced by the crushing clamps may spread, with resulting gangrene at the anastomosis line. A real hazard is to be sure that the crushed ends are open after the anastomosis is complete.

without infection, is not uncommon. Its orifice into the cecum is guarded by a crescentic mucosal fold, absence or incompetence of which may account for the presence of fecal material within the process. The mesoappendix is a triangular peritoneal fold attached to the left, or lower, aspect of the mesentery of the ileum or, if shortened, to the posterior abdominal wall near the pelvic brim.

Although the relation of the base of the appendix to the cecum is constant, the appendix has a wide range of movement and may occupy a great variety of positions (Figs. 503 to 506). It sometimes crosses the psoas muscles, and its apex hangs over the pelvic brim. When the appendix becomes inflamed and fixed to the psoas muscle, stretching of the muscle by extension or hyperextension of the thigh causes pain. This finding is a valuable diagnostic sign. If the appendix hangs over the pelvic brim, it will rest on the pelvic fascia overlying the obturator internus muscle. If the organ becomes inflamed in this situation, the underlying peritoneum and fascia also may become inflamed. Stretching the obturator internus muscle by flexing and rotating the thigh medially causes the patient pain by irritating the overlying fascia and peritoneum (*obturator internus test*). An inflamed appendix in a pelvic position (*pelvic appendicitis*) may result in adhesions connecting it with the rectum and bladder which may produce painful defecation and micturition. An inflamed appendix in a pelvic position in the female is difficult to differentiate from infection of the tube and ovary because of the close relationship of the structures. Pelvic appendicitis or cul-de-sac abscess in the female causes less bladder irritation than in the male, because the pelvic partition in the female protects the bladder. Differential diagnosis is aided by the relation of the pain to the menstrual period and by rectal or vaginal examination.

The appendix may ascend behind the cecum, where its relationship with the peritoneum varies. It may have a mesentery and be free in the retrocecal fossa, be plastered against the posterior aspect of the cecum, lie on the anterior wall of the fossa, or lie against the iliac fascia on the posterior wall of the fossa. An inflamed retrocecal appendix may be attached secondarily to the parietal peritoneum of the

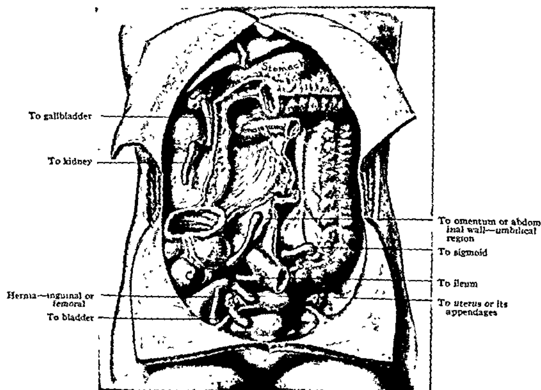


Fig. 503 DIAGRAM TO SHOW THE VARIOUS POINTS OF ATTACHMENT OF AN INFLAMED APPENDIX.
(After Kelly, Hurdon.)

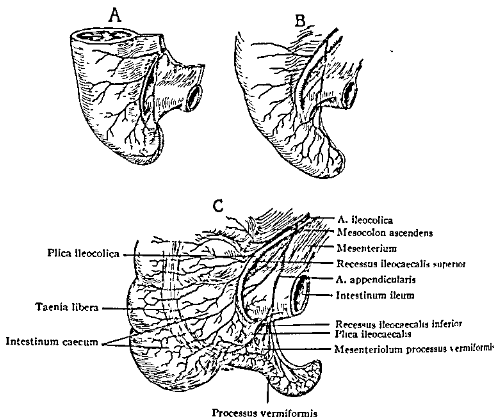


Fig. 502. DEVELOPMENT OF THE CECUM AND APPENDIX, AND THEIR BLOOD SUPPLY. (After Kelly, Hurdon.)

As a rule, the cecum is covered by peritoneum and is freely dependent in the general cavity. Coils of small intestine usually conceal the empty cecum. *The anterior cecal band is a guide to the appendix, as it is continued, with the two other bands, into the outer longitudinal muscle of that structure.*

As a consequence of incomplete development of the colon, the cecum may occupy a high position and lie on the right kidney below the liver. In its low position it may lie in the depth of the pelvis. In the fetus and infant it lies high in the iliac fossa. In adults, and especially in old people, it lies lower down. Its elongation and descent with advancing age favor the presence of the cecum and appendix in the sac of an inguinal hernia. Because of the proximity of the cecum and appendix to the right abdominal inguinal ring, they occasionally present in a right inguinal hernia, even in children. As a result of faulty development, rotation and fixation of the intestine, the ileocecal-appendiceal segment may occupy almost any portion of the abdomen.

Abnormal positions of the cecum have a high degree of practical surgical interest because of the difficulty in diagnosis and the complications they introduce should appendicitis supervene. Occasionally the cecum and colon retain their fetal peritoneal connections and are suspended from the posterior abdominal wall by a mesentery, allowing an abnormal range of mobility. This condition makes it possible for the ileocecal segment to become twisted upon its own mesenteric axis or about an adjacent coil (volvulus), and greatly enhances the occurrence of an intussusception (p. 521).

APPENDIX. The vermiform process, or appendix, attaches to the posteromesial border of the cecum about 2.5 cm. below the ileocecal junction, and can always be located by tracing the anterior longitudinal band distally. The excessive growth of the right wall of the cecum causes the appendix to lie to its medial side. It is uniformly cylindrical and usually is from 6 to 12 cm. long and about 0.8 cm. wide, but the length is extremely variable. Its layers are similar to those of the large bowel. The muscular coat in areas, however, may be so deficient that the peritoneum and mucous membrane are separated only by a thin layer of connective tissue, through which infection can spread easily. Diverticulation of the mucosa, with or

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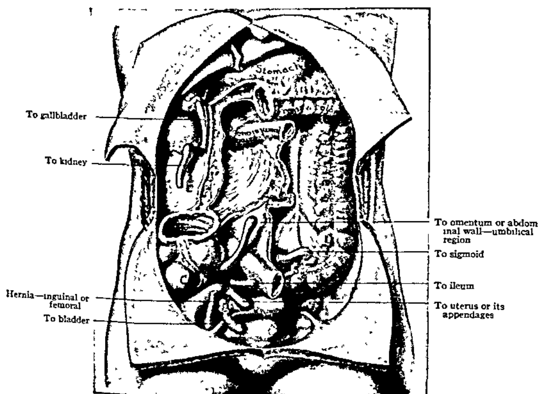


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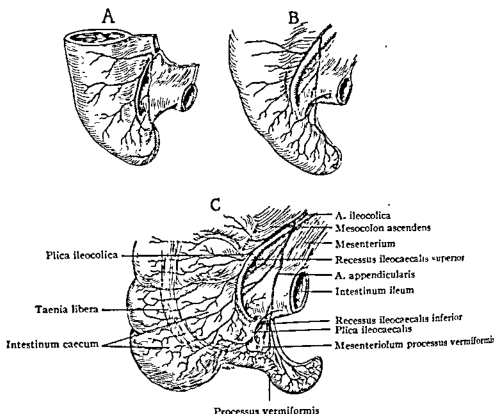


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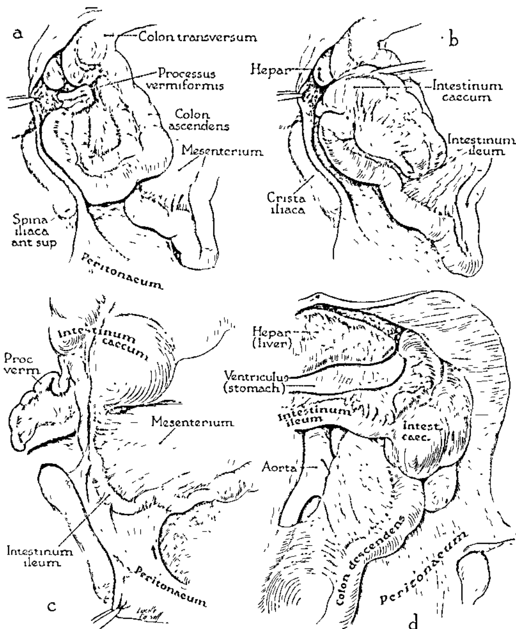


Fig. 505. CECUM, VERMIFORM PROCESS AND ILEUM. VARIATIONS IN FORM AND PERITONEAL RELATIONS (CONTINUED).

a, Cecum situated cranial to a looped ascending colon. *b*, Elongate, redundant type of ascending colon lodged between portions of the terminal ileum. *c*, A case of mobile cecum, situated cranial to the level of the iliac crest; the terminal ileum crosses the iliac fossa. *d*, Malposition of the cecum in a case of *situs inversus viscerum*.

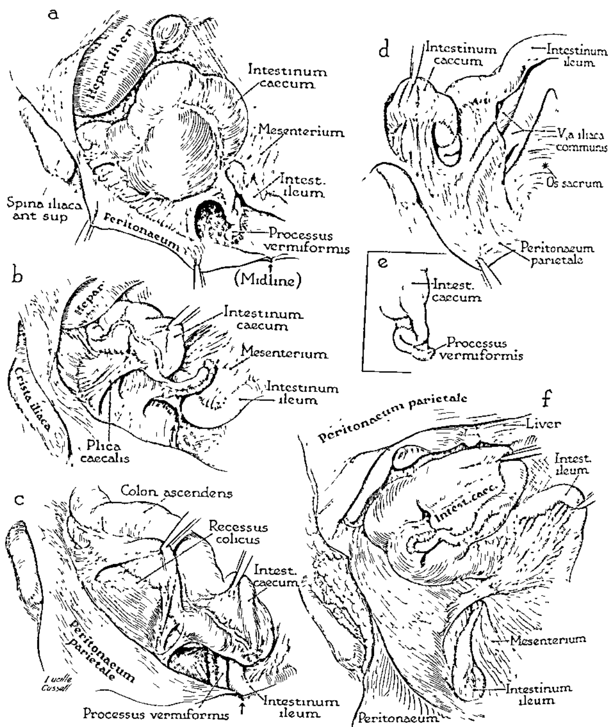


Fig. 504. CECUM, VERMIFORM PROCESS AND ASCENDING COLON. VARIATIONS IN FORM AND PERITONEAL RELATIONS. CECUM LIFTED IN ORDER TO REVEAL UNDERLYING SPACES.

a, Common form of peritoneal reflection, from the dorsal surface of the cecum to the parietal musculature in the iliac fossa The vermiform process (appendix) extends into the lesser pelvis, over the pelvic brim.

b, Showing subsidiary folds of peritoneum situated on the lateral aspect of the cecum. *c*, An example of colic recess of the sort which occurs more frequently in relation to the descending colon. *d*, An appendix lodged in a small inferior ileocecal recess (*e*, inset shows the appendix and the related portion of the cecum). *f*, A case of highly mobile cecum, ascending colon and ileum (the last-named possessing a tall mesentery).

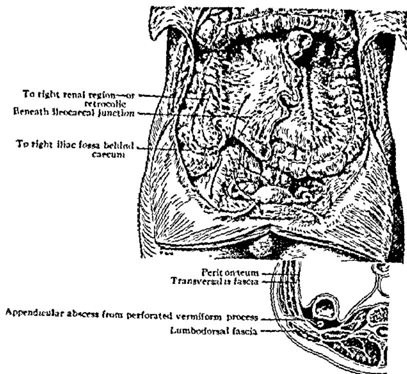


Fig. 507. MORE COMMON PATHS OF INFECTION FROM THE APPENDIX, AND THE USUAL LOCATIONS OF APPENDICEAL ABSCESSES.

Inset is a cross section showing location of a retrocecal abscess.

making the appendicocecal segment more accessible surgically. A fixed cecum, by sliding downward and laterally, may engage in the abdominal inguinal ring and present in the inguinal canal as a hernia with a partial sac or no sac (sliding hernia).

The appendicocecal peritoneum is lifted into folds by vessels which run to the different segments. These folds bound fairly constant peritoneal recesses (Fig. 508).

The *ileocolic fold* is attached over a variable extent to the anterior surface of the mesentery of the terminal ileum and to the anterior aspect to the ascending colon. The free border of the fold, looking downward and to the left, contains the anterior cecal branch of the ileocolic artery. This fold is the anterior boundary of the *superior ileocecal* (*ileocolic*) *recess*, which lies in the angle between the ileum and the ascending colon.

The *ileocecal fold* is relatively avascular, occupies the ileocecal angle, and forms the forward wall of the *ileocecal* (*appendicular*) *recess*. The posterior wall of the fossa is formed by the mesoappendix.

An avascular *retrocecal fold* sometimes extends from the ascending colon and cecum across the lower part of the right paracolic gutter to the peritoneum of the iliac fossa. This fold helps to limit the retrocecal fossa and the beginning of the ascending colon. The depth of the fold depends upon the height at which the peritoneal reflection from the intestine to the iliac fossa or lumbar region occurs. The fossa may be large, and its blind extremity reach to the level of the kidney. The appendix, twisted on itself, often is found here. While these recesses rarely contain small bowel or form intraperitoneal hernias, they have real significance in connection with encysted appendiceal abscesses.

VESSELS AND NERVES. The cecum, the inferior part of the ascending colon, the appendix and the terminal ileum are supplied by the *ileocolic artery*. This vascular distribution is one indication of the anatomic individuality of the ileocecal segment. The artery arises from the superior mesenteric trunk below the transverse portion of the duodenum, and runs downward and to the right across the ureter and psoas major muscle toward the ileocolic angle. It commonly divides into four terminal branches. The anterior and posterior cecal arteries supply corresponding surfaces of the cecum. The

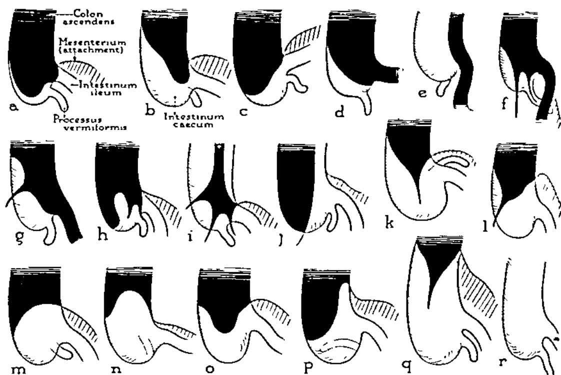


Fig. 506. ATTACHMENT OF THE CECUM, ASCENDING COLON AND ILEUM TO THE DORSAL BODY WALL (AREAS OF FIXATION SHOWN IN BLACK).

Variations, Shown by Representative Types in 125 Adult Specimens. *a*, An instance of almost complete dorsal fixation of the cecum. *b* and *c*, Cases in which the cecum was largely free and in which mobility was increased by presence of a mesenterial support for the terminal portion of the ileum. Because the line of serous reflection from the cecum to the dorsal body is of even contour, retrocecal recesses are wanting, (compare *f* to *i*). *d* and *e*, Specimens in which mobility of the cecum was reduced by fixation of the terminal ileum. *f* to *i*, Examples of occurrence of retrocecal recesses, that is, depressions which occur as offsets from the cecal fossa. *j*, A case in which the cecum and ascending colon were anchored laterally, free medially. *k*, *l*, and *q*, Specimens in which the area of parietal fixation assumed the form of a dart-shaped prolongation, carried downward on the ascending colon and the cecum (*k*, *l*) or only on the colon (*q*). *m* to *p*, Cases in which the cecum, the proximal portion of the ascending colon and the ileum were free of dorsal parietal attachment. In such instances the vermiform process is likely to be retrocecal in position and, occasionally (as in *n*) longer than normal.

false pelvis (Fig. 507). An abscess from a retrocecal appendix becomes walled off, overhung by the cecum and, at times, by the inferior part of the ascending mesocolon.

COLIC (ILEOCECAL) VALVE. The colic valve is located at the entrance of the ileum into the large intestine, opposite the junction of the cecum and ascending colon. *In situ*, it appears as a buttonhole slit. The soft, rounded edges of the valve project prominently into the lumen of the large bowel. The valve consists of an upper and lower segment formed by a duplication of the wall of the small and large bowels (Fig. 508). The circular muscle of the terminal ileum is the ileocolic sphincter; it regulates the flow of chyme into the cecum, preventing regurgitation into the ileum.

PERITONEAL FOLDS AND RECESSES ABOUT THE CECUM AND TERMINAL ILEUM. The cecum and appendix usually have a complete investment of peritoneum, so that all the cecum, or only its caput, hangs free in the iliac fossa much as the heart does in the pericardium. The usual line of peritoneal connection and fixation is at the beginning of the ascending colon. Sometimes part or all of the posterior surface of the cecum, and even the appendix, is fused to the primitive parietal peritoneum of the iliac fossa. Even though the cecum is fixed in this way, a cellular fascial layer lies between it and the actual extraperitoneal tissue. This retrocecal fascia is derived from an embryonic fusion between the dorsal peritoneum of the cecum and the primitive parietal peritoneum of the iliac fossa. By incision of the iliac peritoneum just lateral to the cecum, the cecum can be pulled mesially,

A. APPENDICULARIS
VARIATIONS IN ORIGIN, 225 SPECIMENS

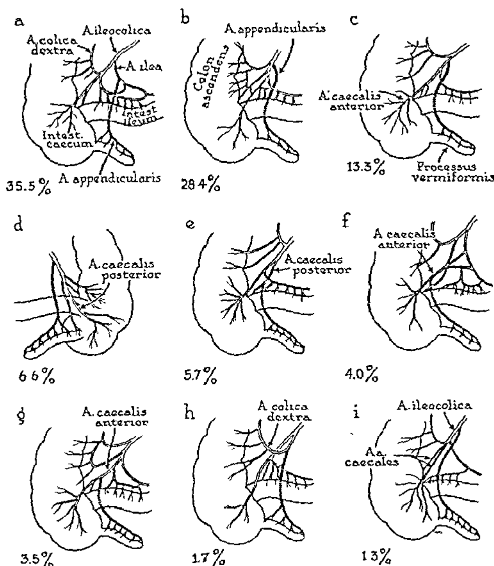


Fig. 509 VARIATION IN ARTERIES OF SUPPLY TO THE VERMIFORM PROCESS, CECUM, ASCENDING COLON AND TERMINAL SEGMENT OF THE ILEUM.

Types arranged in the order of decreasing frequency. It is to be noted that in more than 75 per cent of 225 specimens the artery to the appendix arose from the ileocolic (*b*) close to the point of division, from the ileal division of the ileocolic (*a*) or from the latter's anterior cecal continuation (*c*). Origin from the right colic ramus of the ileocolic (*h*) and high origin from the latter vessel (*i*) are least frequent. (*From* Swigart, Beaton, Anson and Hambley: Unpublished report.)

appendiceal artery, whose source is variable (Fig. 509), runs behind the terminal ileum to the tip of the appendix and sends out *en route* a series of straight branches. It is a terminal vessel, and, if kinked or obstructed entirely, the blood supply of the appendix is cut off, so that gangrene ensues. The ileal artery supplies the terminal ileum.

The *veins* of the ileocecal segment are tributary to the superior mesenteric trunk of the portal, and phlebitis involving them may result in liver abscesses (p. 456).

The *lymphatics* of the cecum and appendix terminate in a group of glands lying about the origin of the terminals of the ileocolic artery (Fig. 517). Excessive enlargement of these nodes may encroach upon the lumen of the terminal ileum sufficiently to cause intestinal obstruction. These lymphatics anastomose with the lumboiliac chain. This connection accounts for infection of the retroperitoneal tissues of the posterior wall of the pelvis following appendicitis.

Surgical Considerations

APPENDICITIS. Certain anatomic conditions predispose the appendix to inflammation, among the principal of which are the relatively large amount of lymphoid tissue within its walls; long, narrow, blind-ended lumen, easily stenosed by inflammation; dependent position; and the tendency to become obstructed by enteroliths.

Attention is directed to the limited anastomosis of the artery of the appendix with the vessels of the cecum. In the event of obstruction of the appendiceal artery from any cause, gangrene of the appendix may supervene. A stricture of the appendix, or varying degrees of obliteration of its cavity, predisposes to recurrent attacks of appendicitis by obstructing the escape of contained fluids into the cecum.

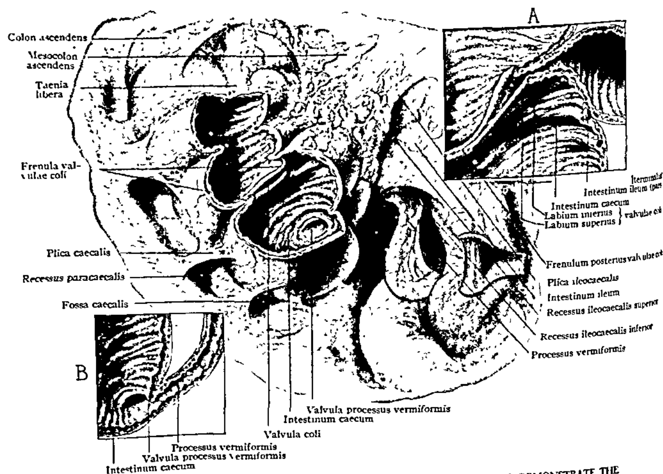


Fig. 508. ILEOCECAL REGION WITH PART OF THE ANTERIOR WALL REMOVED TO DEMONSTRATE THE ILEOCECAL VALVE AND THE ORIGIN OF THE APPENDIX.

A, Detailed drawing of the ileocecal valve; *B*, frontal section through the proximal end of the cecum and appendix.

INTUSSUSCEPTION. An intussusception is a prolapse or invagination of a proximal portion of the intestine into the lumen of an immediately adjoining distal segment. Many cases of acute intestinal obstruction, especially in infants and young children, originate in intussusception. The high incidence in this group is accounted for by the fact that during the first year there is the greatest relative disproportion between the size of the large and small intestines. In older persons an intestinal tumor may be carried along by peristalsis and produce an intussusception.

The most frequent site for an intussusception is the ileocecal region (Fig. 510), possibly because normally the circular muscle coats invaginate into segments of the ileocecal valve.

Certain terms are applied to the parts of a completely developed intussusception. The entering or invaginating tube is the *intussusceptum;* the sheath or receiving tube is the *intussuscipiens;* the apex of the entering or invaginating tube is the *head* of the intussusception; and the junction of the sheathing and entering layers of the intussuscipiens is the *neck.* In the ileocecal form of intussusception the invagination may be so extensive that the head may be palpable in the rectum, or even protrude through the anus. An intussusception may be multiple, thus having two or more invaginating sheaths.

The complications which may result in an unreduced intussusception are gangrene of the whole or part of the entering tube, and obstruction to the passage of the intestinal contents. Swelling of the intussusceptum and oozing of blood into the bowel lumen are common, so that a baby may have evidence of colicky abdominal pain, the presence of a tumor mass, and the discharge of blood-stained mucus from the rectum.

Nonsurgical treatment of intussusception is by careful administration of an enema, with the baby held upside down. In the first few hours of the condition the hydrostatic pressure of the enema may push back the intussusceptum. Surgical treatment consists in laparotomy and reduction of the intussusception by carefully squeezing back the invaginated bowel (Fig. 510). It is not pulled out of the intussuscipiens because inflammatory reaction may have made the tissue soft and friable. Occasionally, manipulation fails to reduce the mass. Resection and anastomosis are now being skilfully done with a low mortality rate. Because of the small lumen of the infant's intestinal tract and the danger of its occlusion, only a single layer of sutures, closely spaced interrupted fine black silk or cotton, should be used. The mortality rate from intussusception runs close to 50 per cent after the first forty-eight hours.

CECAL MOBILITY. The degree of peritoneal fixation of the cecum to the posterolateral abdominal wall varies tremendously (Figs. 504 to 506, 511). Usually it is fairly well fixed in the iliac fossa, but it may be sufficiently long to allow the cecum to lie in the left upper quadrant or any other part of the abdomen. In these circumstances it may become twisted on its

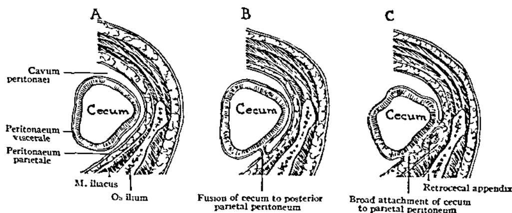


Fig. 511. CROSS SECTIONS AT THE LEVEL OF THE CECUM AND THE ILIAC FOSSA TO SHOW VARIATIONS IN THE DEGREE OF FUSION OF THE CECUM TO THE PERITONEUM.

A, The cecum unattached at this level and quite free to move about. *B,* The cecum held by a narrow mesenteric fold, permitting moderate mobility. *C,* The cecum with a retrocecal appendix bound down to the iliac peritoneum over an extensive area. (From Testut and Jacob.)

SURGICAL ACCESS TO THE APPENDIX. Save in terminal peritonitis, appendectomy is indicated in any state of appendicitis or in the interval between attacks. Even with serious disease the proper preoperative and postoperative use of intravenous fluids, gastroduodenal suction and antibiotics have reduced mortality and morbidity to phenomenally low figures. An appendiceal abscess may subside under conservative management, or require drainage if it is enlarging.

The Davis-Rockey (Fig. 357, *G*) or McBurney (Figs. 356, *M;* 358 to 360) incision gives a good approach to the appendix. Some surgeons prefer a lower abdominal right midrectus incision (Fig. 356, *K*), particularly if the diagnosis is in doubt and a gynecologic condition may be present. It has long been known that the mortality rate following operations for acute appendicitis was higher, the closer the incision came to the midline. The reason was that, in the presence of an appendiceal abscess or localized peritonitis, the more medial incisions spread the infection farther. An appendiceal abscess should be drained through a lateral incision.

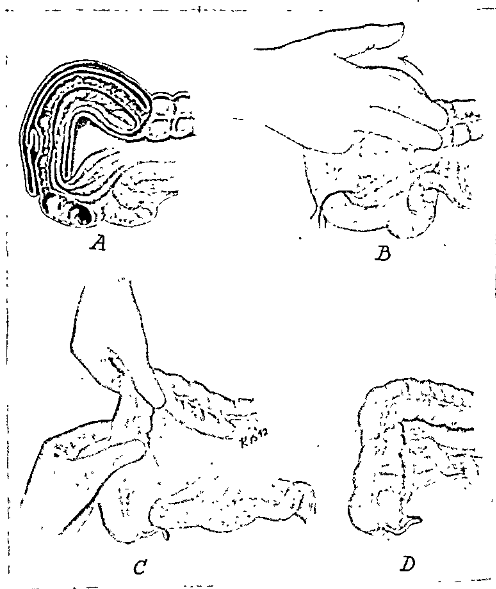


Fig. 510. INTUSSUSCEPTION, WITH METHOD OF REDUCTION.

A, Common ileocecal type. Note appendix on left side. *B*, Stripping or milking back of intussusceptum. *C*, Careful squeezing back process, never pulling out of bowel, since inflammation may have made the tissues soft and friable. The appendix has just emerged. *D*, To prevent recurrent intussusception, some surgeons suture a few centimeters of terminal ileum to the cecum. Recurrent intussusception is rare, so that this procedure may well be left out. (From Orr: Operations of General Surgery.)

state may not exceed that of the thumb, but it is capable of great increase, especially proximal to malignant stricture of the distal extremity of the sigmoid or of the rectum.

The *relations* of the ascending and descending colon to the right and left kidneys explain the resonant note obtained by percussion over renal tumors. The colon may acquire adhesions from an enlarged or inflamed kidney and be in danger of injury in nephrectomy. Nephric and perinephric abscesses have been known to discharge their contents into the colon. The proximity of the hepatic flexure to the inferior surface of the right lobe of the liver explains the adhesions between the liver or gallbladder and the colon, and the possibility of gallstones ulcerating into the colon when such adhesions have formed. Liver abscesses may rupture into this part of the large bowel.

Ascending Colon. The ascending colon lies between the cecum and the right colic (hepatic) flexure, and varies in length as the cecum occupies a high, middle or low position. The inferior margin usually is tangent to the iliac crest, and the upper margin is on a horizontal plane where the right tenth rib crosses the midaxillary line. It is from 12.5 to 20 cm. long.

Posteriorly, the ascending colon is related to the iliac fascia over the iliacus muscle, to the fascia covering the quadratus lumborum, and to the lower part of the right kidney (Fig. 513). It is separated from the kidney by the extraperitoneal and perirenal fat, and the anterior layer of perirenal fascia (p. 412). Its medial

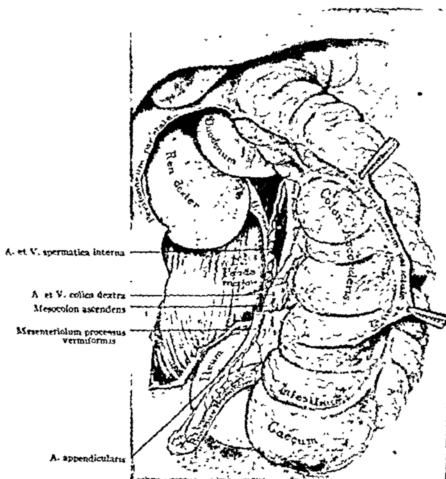


Fig. 513. MOBILIZATION OF THE CECUM AND ASCENDING COLON.

Freeing of the cecum and ascending colon is started by incising the lateral peritoneal reflection at the bowel margin and cleaving the fusion fascia which results from the coalescence of the posterior layer of the ascending mesocolon and right primitive parietal peritoneum. Note the retroperitoneal exposure of the kidney, duodenum and ureter. Care is necessary *not* to injure these structures.

long axis to form a *volvulus.* The cecum is not uncommonly found in a right inguinal hernia. At the time of doing an appendectomy the surgeon is well aware of the varying degrees of cecal mobility, as evidenced by the ease or difficulty in elevating the cecum out through the abdominal incision. Occasionally, patients with a long, mobile cecum complain of attacks of low grade abdominal pain. Relief has been obtained by suturing a mobile cecum to the lateral peritoneum, or by developing vertical peritoneal flaps from this area and suturing them over the cecum to longitudinal bands.

DIVISIONS OF THE COLON AND MESOCOLON

ANATOMIC SUMMARY. The colon begins in the right iliac fossa, distal to the cecum, and terminates opposite the body of the third sacral vertebra, where it becomes continuous with the rectum. With the exception of its terminal portion, its general outline resembles an M or an inverted U. Beneath the arch which it forms lie the coils of the jejuno-ileum and a part of the duodenum (Fig. 512).

The colon is not more than one fourth of the length of the small intestine, and is fixed much more securely. Because of its fixation, its position is much more constant. Two of the subdivisions, the transverse colon and sigmoid colon, however, are suspended by a mesocolon and have a great range of mobility.

In external appearance the large bowel differs decidedly from the small. It has three longitudinal muscle bands, or *taeniae*, which are plainly discernible. Because of the manner in which the taeniae shorten the bowel, it presents a series of pouches or *haustra* separated by transverse furrows. Numerous pedunculated bodies, the *appendices epiploicae*, are attached to the outer serous layer of the colon. They sometimes attain considerable size from the amount of fat deposited within them, and are largest in the sigmoid, this fact being an important distinguishing feature of that segment.

The size of the colon diminishes gradually from a diameter of 6 cm. at its cecal extremity to 2.5 cm. at the termination of the sigmoid colon, which usually is narrowest. The diameter of the colon in an empty and contracted

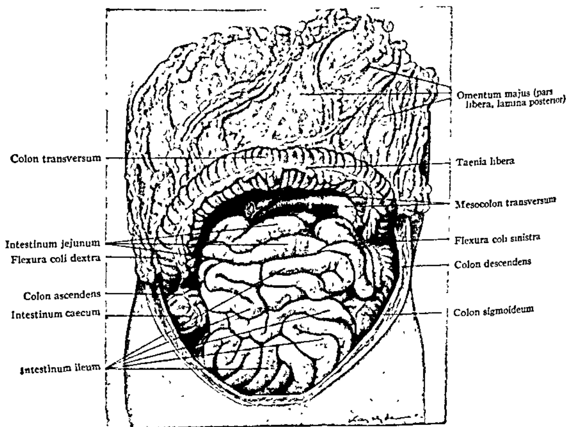


Fig. 512. RELATIONS BETWEEN THE LARGE BOWEL AND THE JEJUNO-ILEUM.

a mobile ascending colon makes on the superior mesenteric artery may cause that artery to compress the transverse portion of the duodenum against the lumbar column sufficiently to cause symptoms of duodenal obstruction requiring duodenojejunostomy. The ascending colon throughout its length may be sutured to the posterior parietal peritoneum, or, better still, a vertical split may be made in the peritoneum and the two edges sutured over the colon to the longitudinal bands.

RIGHT COLIC (HEPATIC) FLEXURE. The right colic flexure, formed by the junction of the ascending colon and the transverse colon, lies under the ninth and tenth costal cartilages in the interval between the inferior surface of the right lobe of the liver and the anterior surface of the lower pole of the right kidney. It is related by its medial surface to the fundus of the gallbladder anteriorly, and to the descending duodenum posteriorly. A peritoneal band from the gastrohepatic (lesser) omentum, or hepatoduodenal ligament, sometimes passes downward from the right extremity to the flexure, and is known as the *hepatocolic ligament*. Not infrequently a peritoneal fold leaves the peritoneal surface of the right lobe of the liver to spread out over the colic flexure. The right flexure occasionally has an adhesion, the *cysticocolic ligament*, between itself and the gallbladder. By cleaving the embryologic fusion fascia behind the flexure, the colic angle may be mobilized sufficiently to render its excision possible.

TRANSVERSE COLON. The transverse colon crosses the abdominal cavity from the right to the left colic flexure with a downward curve. In recumbency it reaches its lowest position in the midline at, or a little below, the umbilicus. In many patients it lies at a much lower level because of its excessive length, as in cases of undescended cecum and in excessive length of the transverse mesocolon. In the erect position the transverse colon descends and often lies behind the symphysis; both flexures become acute, and the proximal part of the transverse colon descends in front of, or just mesial to, the ascending colon. Should these adjacent portions of large bowel become attached to each other by peritoneal adhesive bands, the kinking becomes permanent and may give rise to obstructive phenomena. *Identity of the transverse colon* can always be established by finding the great omentum attached to its supero-anterior surface (Fig. 512).

The right and more fixed portion of the transverse colon is related to the gallbladder, with which it has been known to form a fistulous communication through which gallstones may be extruded into the large bowel (p. 464). The left segment is related closely to the greater curvature of the stomach and ascends slightly as it approaches the splenic flexure. Between the flexures the transverse colon is connected to the posterior abdominal wall by the transverse mesocolon.

TRANSVERSE MESOCOLON. The transverse mesocolon forms a horizontal partition across the abdominal cavity, suspending the transverse colon from the posterior abdominal wall and separating the cavity of the omental bursa and the supramesocolic structures from the inframesocolic compartment (Figs. 512, 514). It is the natural barrier to reciprocal infections between these areas. The posterior parietal attachment of the transverse mesocolon is to the anterior surface of the head, neck and body of the pancreas, but it may extend farther to the right and cross the anterior surface of the descending duodenum.

GREATER OMENTUM. The greater omentum develops from the primitive peritoneal duplication, the dorsal mesogastrium, which extends from the greater curvature of the stomach to the posterior abdominal wall (Fig. 401) independently of the colon and transverse mesocolon. As the stomach assumes its ultimate position in the abdomen, this fold bulges to the left and develops in a forward and downward direction until it forms a baglike structure, the mesogastric (omental) bursa. The epiploic foramen or open end of this pouch is directed to the right, and the closed lower end enlarges downward until it hangs over the transverse colon and mesocolon and the small intestine and becomes the greater omentum.

Toward the middle of intrauterine life the posterior layer of the greater omentum fuses with the serosal layer of the transverse colon and mesocolon, with which it is in contact. Often in the infant, and occasionally in the adult, the cavity of the greater omentum remains open below the level of the transverse colon. Generally, however, the cavity of the greater omentum is obliterated to within a short distance of the greater curvature of the stomach

aspect is related to the psoas muscle and the descending duodenum. The ascending colon separates the right paracolic gutter from the right inframesocolic compartment, and is bound to the posterior abdominal wall by the peritoneum clothing its posterior surface. At times the right margin of the great omentum is fused with the peritoneum of the ascending colon, in which instance the right half of the transverse colon often comes into approximation with the ascending colon, forming a "double-barreled" arrangement.

The ascending colon and mesocolon, primitively suspended by a dorsal common mesentery, after rotation lie intimately against the right primitive parietal peritoneum (Fig. 514). The serous surfaces in apposition coalesce into a fusion fascia, which, in the kidney region, is known as Toldt's fascia. In resection of the ascending colon the peritoneum along the lateral margin of the bowel is incised, and the colon is drawn medialward by blunt cleavage of the fusion fascia. In this manipulation neither the vessels in the ascending colon and in its mesocolon, nor the ureter and vessels to the kidney, lying deep to the fusion fascia, are injured.

When the ascending colon is supplied (as primitively) with a mesocolon, the ascending colon falls away from the loin and drags the hepatic flexure and the cecum with it. While this condition of mobile ascending colon may be symptomless, it may play an important part in cecal stasis, cecal volvulus (p. 522) and ileocecal intussusception (p. 521), and perhaps in mobility of the right kidney. The drag which

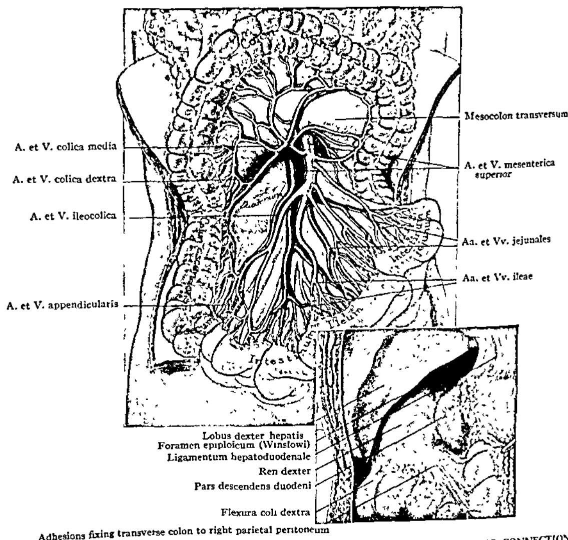


Fig. 514. ASCENDING AND TRANSVERSE COLON AND MESOCOLON, WITH VASCULAR CONNECTIONS.
Considerable variation occurs in these vessels. Inset shows method of fixation of right colic angle and right portion of the transverse colon. Note how the retroperitoneal duodenum lies close to the colon.

is divisible into a fixed (iliac) and a mobile (pelvic) segment.

The *iliac segment* is that part of the sigmoid flexure which lies in the iliac fossa and has no mesentery. It descends on the iliacus muscle to the level of the anterior superior iliac spine, and turns mesially just above and parallel to the inguinal ligament. It extends to the pelvic brim, where it becomes continuous with the pelvic colon. A tumor of the iliac colon may sometimes be recognized by rolling the gut against the ilium.

The *pelvic segment*, or mobile division of the sigmoid, is a long, omega-shaped coil of bowel continuous above with the iliac colon and below with the rectum. It is suspended from the posterior wall of the pelvis by a mesentery, the *pelvic mesocolon*. The line of mesenteric attachment resembles an inverted V. It begins at the mesial border of the psoas major muscle and passes upward and medially and then downward to end typically in front of the third sacral vertebra. The terms "ascending" and "descending" limbs indicate the segments of gut which this arrangement of the mesentery encloses. The length, location and degree of mobility of the loop and the length of its mesentery are subject to wide variation. Usually the pelvic colon is situated partly in the pelvis and partly in the abdomen. When it has a long mesocolon, it may cross the median line, where, not infrequently, it comes into view in the course of an appendectomy. In such a circumstance failure to find the appendix is often due to the fact that the operator is searching along the sigmoid colon instead of the cecum. Differentiation is easy, because the sigmoid has large epiploic appendages. In certain instances the pelvic colon is short, presents no loop, has little mesentery, and passes directly from the iliac colon into the rectum. This disposition of the colon is unsuitable for permanent colostomy.

The *intersigmoid recess* is a small, funnel-shaped pouch commonly present at the junction of the two roads of the sigmoid mesocolon. In this recess may lodge a loop of small bowel, which, by a process of cleavage, may insinuate itself between the mesocolon and the primitive parietal peritoneum and form a not uncommon variety of internal or intraperitoneal hernia.

VESSELS OF THE COLON. The arterial supply to the ascending colon, right colic (hepatic) flexure, and transverse colon is derived from the right and middle colic branches of the SUPERIOR MESENTERIC ARTERY (Figs. 515, 516). The left colic branch and the sigmoid arteries from the inferior mesenteric artery supply the descending and sigmoid portions of the colon (Fig. 516).

The *right colic artery* arises just above, or in common with, the ileocolic artery and runs behind the peritoneum of the right inframesocolic space. Near the bowel it divides into a descending branch which anastomoses with the colic branch of the ileocolic artery and an ascending branch which anastomoses with the right branch of the middle colic artery. Both these branches supply the ascending colon (Fig. 514).

The *middle colic artery* arises from the superior mesenteric at the lower margin of the pancreas and runs in the transverse mesocolon, where it divides into right and left branches which anastomose with the right and left colic arteries (Figs. 496, 515). The right branch supplies the right third of the transverse colon; the left, the left two-thirds. Since the main trunk lies to the right of the midline, an operative opening through the transverse mesocolon is made on the left side.

The INFERIOR MESENTERIC ARTERY, through its left colic, sigmoid and superior hemorrhoidal branches, supplies the descending and sigmoid colon and the proximal part of the rectum (Fig. 515). The inferior mesenteric artery arises from the aorta about 10 cm. above the bifurcation. As it runs downward and slightly to the left, it gives off the *left colic artery* to the descending colon and part of the transverse colon, and the *sigmoid arteries* to the iliac and pelvic segments of the sigmoid colon.

The several sigmoid arteries anastomose freely with one another to form arterial arches and a marginal artery in the pelvic mesocolon. The uppermost of these arteries anastomoses with the descending branch of the left colic artery. The lowermost sigmoid artery has no marginal connection with the superior hemorrhoidal artery, but generally anastomosis in the region is good. The inferior mesenteric artery, beyond the region of the lowest sigmoid artery, continues downward into the pelvis on the dorsal surface of the rectum as the *superior hemorrhoidal artery* (p. 597). This anastomo-

by adhesion between the apposed serous surfaces, so that the omentum appears to arise from the convexity of the transverse colon. Obliteration on the left is not as complete as on the right, so that the unobliterated interval on the left between the stomach and transverse colon offers readier access to the cavity of the lesser sac. That part of the greater omentum connecting the greater curvature of the stomach with the transverse colon is the *gastrocolic ligament*. The greater omentum spreads over the large and small bowel and helps to anchor the colic angles by fusing to the diaphragm.

Left Colic (Splenic) Flexure. Because of the small left lobe of the liver, the left colic flexure is placed higher than the right, and its angle is more acute than that of the hepatic flexure (Fig. 515). The splenic flexure may overlie the left kidney anywhere from its upper to its lower pole; it is located deeply under cover of the costal margin and is partly overlaid by the stomach. Examination of the flexure is difficult, and tumors escape early recognition. The upper and forward aspects of the flexure receive an attachment from the left margin of the greater omentum, and the posterior aspect is attached to the pancreas by the left extremity of the transverse mesocolon. From the lateral aspect of the flexure the peritoneum passes to the diaphragm as the *left phrenicocolic ligament*. The inferior pole of the spleen rests upon the ligament, which, in consequence, is known also as the supporting ligament of the spleen.

Descending Colon. The descending colon varies from 8 to 12 cm. in length, and extends from the left colic flexure to the iliac crest. In its descent it inclines mesially, curving around the lower extremity of the left kidney. Its posteromesial aspect lies directly upon the fascia covering the quadratus lumborum muscle; the remainder of the descending colon is covered by peritoneum. The descending colon is more deeply placed than the ascending colon, and rarely has a mesentery.

Sigmoid Colon and Mesocolon. The sigmoid colon or flexure begins at the iliac crest and terminates at the third sacral vertebra. It

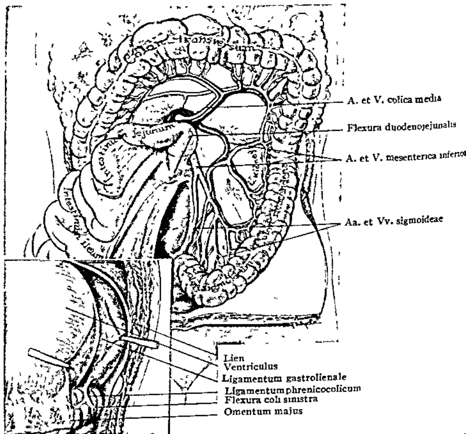


Fig. 515. TRANSVERSE DESCENDING AND SIGMOID PORTIONS OF THE COLON AND ITS MESOCOLON, WITH THEIR VASCULAR CONNECTIONS.

The inset shows the peritoneal connections at the left colic angle and their relations to the spleen.

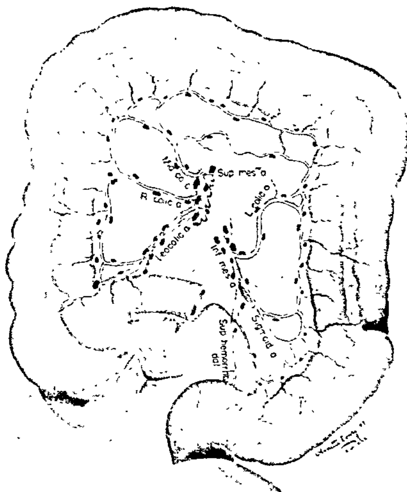


Fig. 517. ARTERIAL SUPPLY AND LYMPH NODES OF THE COLON.

Epiploic nodes lie in the wall of the bowel and epiploic appendages (not shown). *Paracolic glands* are situated along the mesenteric margin. *Intermediate glands* follow the main colic arteries, and *central* or *main glands* cluster about the origin of the vascular trunks. (From McKittrick: Surg., Gynec. & Obst., 87: 15–25, 1948.)

ally the lymph flow coincides with the venous flow, but retrograde metastases may occur if channels are completely blocked. The lymphatic drainage of the rectum is presented later (p. 597).

Surgical Considerations

Surgery of the colon is concerned chiefly with resections for carcinoma or serious inflammatory processes, such as chronic ulcerative colitis or diverticulitis. The colon is not often involved in obstruction from adhesions.

THE SURGICAL SIGNIFICANCE OF REGIONAL LYMPHATIC DRAINAGE OF THE HEPATIC FLEXURE. Because of variance of opinion regarding the ideal point of ligature of the middle colic artery during the performance of right hemicolectomy for carcinoma of the proximal colon, Phillips, Waugh and Dockerty studied the lymphatic drainage of surgical specimens removed for cancer of the hepatic flexure. The problem centers around two important fundamental issues: namely, the desirability of complete extirpation of the regional lymph channels draining a malignant lesion, and the maintenance of an adequate blood supply to the anastomosis and remaining intestine after resection. Those advocating removal of the entire middle colic artery point out that this step is necessary for the excision of the entire middle colic lymph chain. Others have been fearful that removal of the middle colic artery in its entirety would jeopardize the arterial blood supply to the anastomosis and the

ses below with branches of the middle and inferior hemorrhoidal arteries.

At one time the blood supply of the terminal sigmoid and upper rectum was considered to be precarious, and the term *Sudeck's critical point* designated a point on the inferior mesenteric artery located above the origin of the last sigmoid artery as the safest site for ligation to ensure maintenance of blood supply after mobilization of the rectosigmoid and rectal portions of the gut. Modern surgical experience does not bear out the presence of such a critical spot, resections being done in this area without difficulty. There are many variations in the blood supply of the colon (Figs. 496, 497), and in general a rich collateral circulation is present in the distal arches. Dixon* in describing low anterior resection and primary anastomosis, states:

The low rectal stump can survive if supplied by the inferior hemorrhoidal vessels alone, and Sudeck's point is not as critical as described. . . . In determining the point of ligation of the inferior mesenteric or superior hemorrhoidal vessels, my colleagues and I do not recognize any critical point, rather depending on the precepts of rational cancer surgery and providing the correct amount of excision to allow the sigmoid or descending colon to reach or bridge to the rectal or rectosigmoid section without transsection. . . . If one does not feel certain of the pattern of the circulation to the upper segment, instead of depending on the color of the intestine it seems wiser to look for the pulsations in the arteries as they enter the colonic wall.

* Ann. Surg., 128: 425–42, 1948.

The VEINS correspond largely to the arteries and join the superior and inferior mesenteric trunks which send their blood to the portal vein (Figs. 515, 516).

The LYMPH VESSELS of the large bowel follow mainly the course of the chief blood vessels (Fig. 517), and a knowledge of their location is necessary if the surgeon intends to cure cancer by eradicating both the local lesion and the area of possible lymphatic spread. About 60 per cent of the patients operated upon for carcinoma of the colon and rectum have metastases to regional nodes. The size of the local lesion is no criterion of the presence or absence of nodal metastases, which may be present without gross enlargement of the glands. Usu-

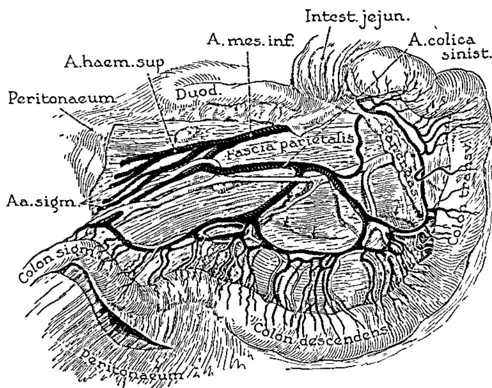


Fig. 516. LEFT COLIC AND SIGMOIDAL ARTERIES AND VEINS IN RELATION TO THE RENAL FASCIA AND THE LEFT KIDNEY

The medial margin of the kidney is indicated by arrows. (From Daseler and Anson: J. Urol., 49: 789–802, 1943)

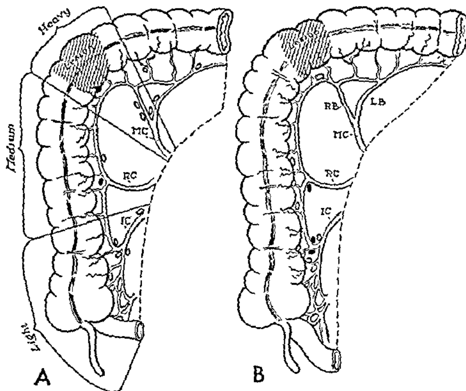


Fig. 519. Right colic and ileocolic lymphatic chain draining the region of adenocarcinoma of the hepatic flexure. Metastatically involved lymph nodes shown by solid black ovals.

(From Phillips, Waugh and Dockerty: Surg., Gynec. & Obst., 99: 455–61, 1954.)

inoperable distal malignancy requires short-circuiting. In the first instance the opening is usually single-barrelled. For the permanent, double-barrelled colostomy (Fig. 521) fixation of the loops outside the abdomen is aided by closing the anterior and posterior rectus fascia and skin between the proximal and distal segments. The colon should never be sutured to any layer of the abdominal wall, since fecal fistulae often develop from such suture sites.

The location of the colostomy is varied with the situation. For the single-barrelled colostomy after resection of the rectum, a left lower quadrant position is commonly selected, although some surgeons prefer the lower abdominal midline site. A left or right upper quadrant transverse colon colostomy is ideal for placing the left colon at rest.

Resection of the Right Colon. A mid-abdominal transverse incision (Fig. 358, *F*) gives good exposure for resection of the segments shown in Figure 522, *A-A'* or *A-B*. The bowel is first freed laterally by incising the peritoneum (Fig. 513), and then is dissected up from the retroperitoneal structures, care being taken to protect the ureter and retroperitoneal duodenum. Above, it is freed from renal, gall-bladder and gastric attachments. Note that, to remove as many lymph nodes as possible, the line of final resection divides the main vessels right at their superior mesenteric origin. After the resection ileocolic continuity is restored by an end-to-end or end-to-side anastomosis between freely bleeding margins of the bowel. No attempt is made to peritonealize the large raw area along the right flank.

Midtransverse Colon Resections. Wide removal of the central part of the transverse colon and mesentery (Fig. 523, *A-A'*) with direct end-to-end anastomosis is not difficult, and open or closed methods (Figs. 499, 500) of handling the bowel can be used.

Resections of the Left Colon. Long segments of bowel are here resected in order to excise the lymph nodes about the origin of the inferior mesenteric vessels (Fig. 522, *E-D*; Fig. 523, *B-C*, *B-D*, *E-F*). The remaining ends, as demonstrated in the illustrations, often appear to be widely separated, but in life the transverse colon hangs close to the sigmoid

residual transverse colon, and have compromised with excision of only the right branch of the vessel.

As shown in Figure 518, removal of the right branch of the middle colic artery would permit removal of the epicolic, paracolic and intermediate groups of nodes, but would leave remnants of the main group of nodes in situ.

To determine the lymphatic spread of nine specimens of hepatic flexure carcinoma, each specimen at the time of surgery had 5 cc. of a 4 per cent aqueous solution of pontamine, to which had been added 30 turbidity-reducing units of hyaluronidase, injected through a small needle into the muscularis externa at the site of the lesion. Multiple injections seemed to distribute the dye around the immediate periphery of the lesion. The results showed that for all nine specimens the dye diffused sufficiently throughout the lymphatics accompanying the right branch of the middle colic artery, and the main trunk of this vessel, so that nodes in the epicolic, paracolic, intermediate and main groups were stained. No lymphatic staining was evident in the region of the left branch of the middle colic artery except in one case, wherein a single, lightly stained, intermediate group node was found. In seven specimens the dye was taken up by the middle colic lymphatic channel only and did not appear in the ileocolic or right colic lymphatics. In the eighth and ninth specimens the dye had diffused through multiple channels. One of these (Fig. 519, *A*) had dye staining along the middle colic, right colic and ileocolic arteries in order of decreasing intensity. That carcinomatous metastasis went this way also is shown by a metastatically involved paracolic lymph node adjacent to a branch of the right colic artery. The other specimen of multiple channels of dye spread (Fig. 519, *B*) also had metastatic carcinoma involving one right colic node and two ileocolic nodes.

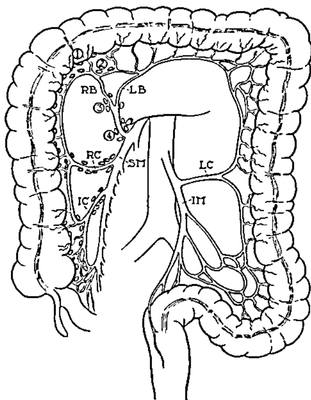


Fig. 518. LYMPHATICS OF THE RIGHT SIDE OF THE COLON.

1, Epicolic nodes; 2, paracolic nodes; 3, intermediate group nodes; 4, main group nodes. Superior mesenteric artery (*SM*); ileocolic artery (*IC*); right colic artery (*RC*); right branch of middle colic artery (*RB*); left branch of middle colic artery (*LB*); left colic artery (*LC*); inferior mesenteric artery (*IM*). (From Phillips, Waugh and Dockerty: Surg., Gynec. & Obst., 99: 455–61, 1954.)

Phillips, Waugh and Dockerty's conclusion was that, because of the ease and relative impunity of extending the scope of a right hemicolectomy, and because of the possibility of metastatic involvement of the main group of nodes (Fig. 520) the procedure should ideally include ligation of the middle colic artery at its origin, with removal of the main group of middle colic nodes whenever feasible.

COLOSTOMY. By colostomy is meant the establishment of an opening between some portion of the colon and the skin, in order to form an artificial anus.

A *temporary colostomy* is designed to relieve colonic obstruction or to put the distal bowel at rest, with later a restoration of the continuity of the colon. The selected sites are usually the transverse colon or sigmoid. The operation is done simply by drawing a loop of the colon out through a suitable small wound and closing the layers of the abdominal wall not too tightly about the two bowel segments. A tube placed through the mesentery (Fig. 521) holds the bowel above the skin level until adhesions fix it to the abdominal wall. Closure of a colostomy is best done by excising it from the abdominal wall, cutting away all scar tissue from the colon loops, and doing what is practically an end-to-end anastomosis of the freshened open bowel edges.

A *permanent colostomy* is done when the distal bowel has been resected or when an

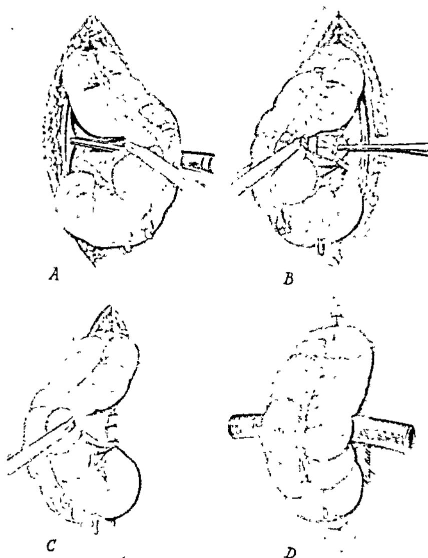


Fig. 521. DOUBLE-BARRELLED LOOP COLOSTOMY OF PERMANENT TYPE.

A, Loop of colon delivered through the abdominal wound and held with tape. *B*, Posterior rectus fascia sutured beneath the loop. Anterior rectus fascia can be similarly closed for 1 cm. length. *C*, Skin closed beneath the loop. *D*, Soft rubber tube placed through the mesentery beneath the loop. (From Orr: Operations of General Surgery)

vomiting is an early and persistent occurrence. This follows the general rule that, in intestinal obstruction, the higher the seat of obstruction, the more likely vomiting is to occur early, because of the greater fluidity of the contents higher in the intestinal canal.

INTESTINAL EXCLUSION. By intestinal exclusion is meant the diverting of the intestinal contents from some limited part of the intestinal tract by means of a short-circuiting operation which does not interfere with the intestinal flow in the remainder of the bowel. When a lesion which cannot or should not be removed obstructs the colon or the colon requires rest, this procedure is adopted. The lesion must be located at some point below which sufficient uninvolved bowel is available for an anastomosis. Exclusion is accomplished by uniting two portions of the bowel so that the content of the upper or proximal part empties into the lower or distal portion without traversing the interposed loop.

The intermediate or short-circuited portion is said to be partially excluded when some part of the intestinal flow occurs through one or the other end of the short-circuited part into the

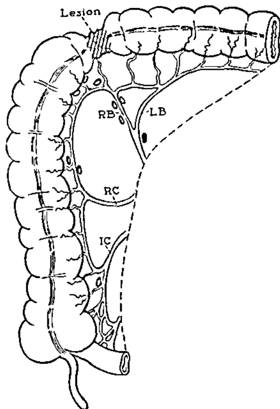


Fig. 520. CASE OF ADENOCARCINOMA OF THE HEPATIC FLEXURE WITH METASTATICALLY INVOLVED LYMPH NODE ADJACENT TO THE MAIN BRANCH OF THE MIDDLE COLIC ARTERY.

Failure to excise the entire middle colic artery would have left this involved lymph node in situ. (From Phillips, Waugh and Dockerty: Surg., Gynec. & Obst., 99: 455–61, 1954.)

or upper rectum; consequently approximation is not difficult. The left ureter must be identified and carefully protected in its retroperitoneal position and also at the point where it passes over the brim of the pelvis (Fig. 544).

A *complete left colectomy*, excising the left side as widely as the accepted right colectomy, is being done as a routine procedure for all carcinomas of the left colon (Figs. 522, *E-D*; 524). With ligation of the inferior mesenteric artery at its origin from the aorta and removal of the mesentery beyond the midline, all the left colic lymph nodes and the central group are excised. Bowel continuity is established by anastomosing the transverse or descending colon to the rectum. These steps are described in the following paragraphs.

LIGATION OF INFERIOR MESENTERIC ARTERY AND PREAORTIC LYMPHADENECTOMY. Ligation of the inferior mesenteric artery has been carried out in a sufficient number of cases to establish it as a safe procedure. It is usually done in instances of carcinoma of the left colon or rectum. The blood supply to the remaining intestines has been quite sufficient to support a permanent left colostomy after a combined abdominoperineal resection or an end-to-end anastomosis of the splenic flexure, descendens, or upper sigmoid to the rectum. To avoid the possibility of a gangrenous bowel, it has been routine to require a good flow of blood coming through the open end of the marginal artery after the inferior mesenteric artery has been divided.

Ligation and section of the inferior mesenteric artery at its origin facilitate a preaortic lymphadenectomy from the level of the duodenum downward. The procedure should be carried out in all cases of carcinoma of the left colon and rectum with careful skill, leaving the great midline vessels bare (Fig. 525).

VOLVULUS. Volvulus is a term used to denote certain forms of twisting of the intestine. In one form, and much the commonest, the bowel is twisted around its mesenteric axis. In other forms the bowel is wound about some neighboring coil, a postoperative adhesive band or certain of the remains of the vitello-intestinal duct.

The sigmoid colon is concerned in by far the majority of the recorded instances of volvulus, since it affords the most favorable predisposing conditions. The loop of the sigmoid colon varies considerably in length, and its extremities are comparatively close to one another. The gap between the two may be diminished further as a result of the traction exercised upon the mesentery by the loaded condition of the bowel, common in chronic constipation. Under traction the pelvic mesocolon elongates considerably. A twist of the loop occurs readily, and the bowel becomes distended and the vessels constricted by the mutual pressure of the two ends of the loop. The obstruction to the venous return causes the twisted loop to become greatly swollen and edematous, so that it assumes a livid hue. The arterial flow subsequently is arrested; and, if the vascular constriction remains unrelieved, gangrene of the loop ensues. While these changes are occurring, the bowel distends and rises gradually until it may fill the greater part of the abdominal cavity and come into contact with the liver or compress the diaphragm.

In volvulus of the sigmoid, signs of obstruction come on slowly, and vomiting is a late manifestation. In volvulus of the small bowel,

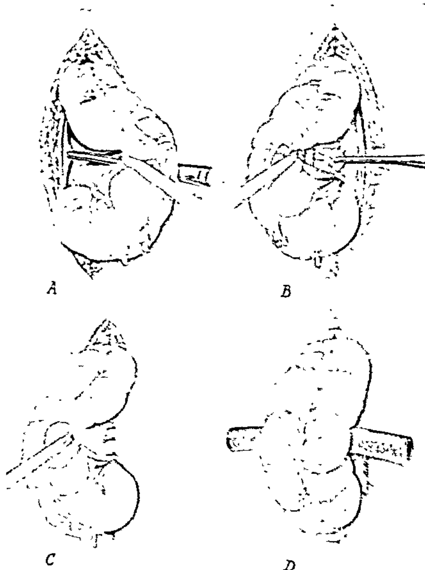


Fig. 521. DOUBLE-BARRELLED LOOP COLOSTOMY OF PERMANENT TYPE.

A, Loop of colon delivered through the abdominal wound and held with tape. *B*, Posterior rectus fascia sutured beneath the loop. Anterior rectus fascia can be similarly closed for 1 cm. length. *C*, Skin closed beneath the loop. *D*, Soft rubber tube placed through the mesentery beneath the loop. (From Orr: Operations of General Surgery.)

vomiting is an early and persistent occurrence. This follows the general rule that, in intestinal obstruction, the higher the seat of obstruction, the more likely vomiting is to occur early, because of the greater fluidity of the contents higher in the intestinal canal.

Intestinal Exclusion. By intestinal exclusion is meant the diverting of the intestinal contents from some limited part of the intestinal tract by means of a short-circuiting operation which does not interfere with the intestinal flow in the remainder of the bowel. When a lesion which cannot or should not be removed obstructs the colon or the colon requires rest, this procedure is adopted. The lesion must be located at some point below which sufficient uninvolved bowel is available for an anastomosis. Exclusion is accomplished by uniting two portions of the bowel so that the content of the upper or proximal part empties into the lower or distal portion without traversing the interposed loop.

The intermediate or short-circuited portion is said to be partially excluded when some part of the intestinal flow occurs through one or the other end of the short-circuited part into the

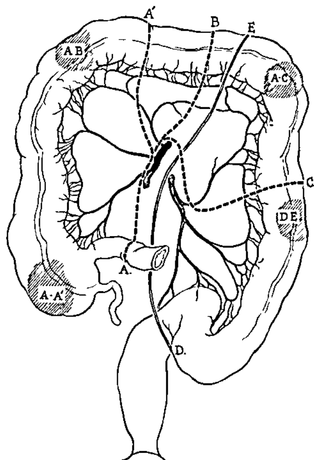


Fig. 522. AREAS OF EXCISION FOR CARCINOMA OF THE COLON.

Segments of bowel and lymph node-containing mesentery to be removed for carcinoma of the cecum, *A-A'* or, preferably, *A-B;* hepatic flexure, *A-B;* splenic flexure, *A-C;* and descending colon, *D-E.* (Modified from McKittrick: Surg., Gynec. & Obst., 87: 15–25, 1948.)

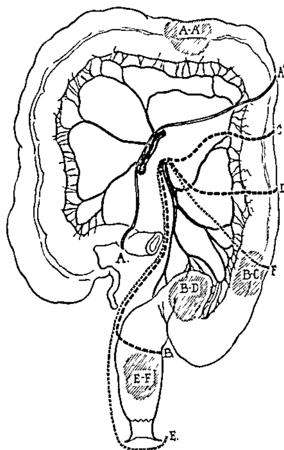


Fig. 523. AREAS OF EXCISION FOR CARCINOMA OF THE COLON (CONTINUED).

Segments of bowel and lymph node-containing mesentery to be removed for carcinoma of the transverse colon, *A-A';* the apex of the sigmoid, *B-C;* the lower sigmoid or rectosigmoid, *B-D;* and the low rectum, *E-F.* (Modified from McKittrick: Surg., Gynec. & Obst., 87: 15–25, 1948.)

remainder of the bowel. A *partial exclusion* of the large bowel is obtained by a side-to-side ileocolostomy. In this procedure the ileum just proximal to the cecum is anastomosed with either the sigmoid or the transverse colon to allow the major part of the bowel contents to pass directly from the ileum into the terminal colon, thus short-circuiting to a degree the interval of large bowel proximal to the anastomosis.

Complete exclusion of a segment of bowel requires more than a simple side-to-side short-circuiting anastomosis, since, unless there is an organic or spastic constriction involved, a part of the feces continues to pass into the short-circuited loop. Complete exclusion requires that the ileum be divided near the cecum and its distal extremity closed or brought out through the abdominal wall for drainage purposes. The proximal ileum then is anastomosed to the transverse colon or sigmoid, or formed into a proximal ileostomy. A double-barrelled colostomy is also commonly used as a complete exclusion procedure (Fig. 521).

DIVERTICULA OF THE COLON (DIVERTICULOSIS) AND DIVERTICULITIS. Diverticula of the large bowel (*diverticulosis*) present mainly in the sigmoid, and are herniations of areas of mucosa and submucosa through interstices in the muscle coats, "blowouts of the inner tube of mucosa." They probably develop along the course of the blood vessels penetrating the intestinal wall (Fig. 526), and usually are innocuous. Diverticula perforating the wall through a narrow opening and ballooning out the peritoneal covering are those most likely to become inflamed. The muscularis is thin or disappears except at the neck of the diverticu-

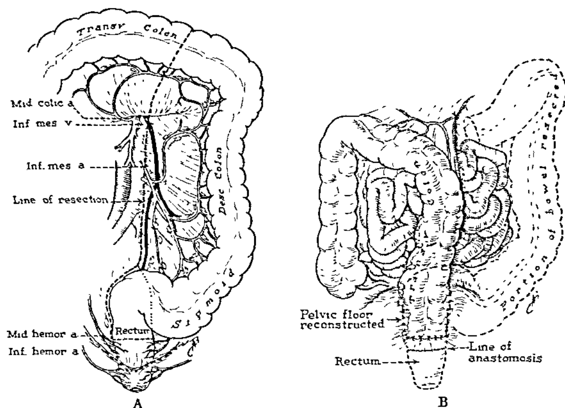


Fig. 524. COMPLETE LEFT COLECTOMY.

A, By resection of bowel from the transverse colon to the rectum, this procedure can be applied to all carcinomas of the left colon from the splenic flexure to the upper rectum. Ligation of the inferior mesenteric artery at its origin from the aorta allows removal of all left colon mesentery and lymph nodes. *B*, Completed operation. The transverse colon bridges over the loops of small bowel and is anastomosed to the rectum. A new pelvic floor is reconstructed. (From Rosi: Quart. Bull., Northwestern Univ. M. School, 23: 376–83, 1949.)

lum. Intestinal contents entering the diverticulum set up inflammatory changes and ulceration.

Although walling off by adhesions is more active in *diverticulitis* than in appendicitis, internal fistulae may occur from ulceration into neighboring viscera. The urinary bladder is the organ ordinarily involved in this unusual anastomosis. The sigmoid mesocolon may become infiltrated and thickened by inflammation, or even become the seat of an acute abscess which may open through the abdominal wall or into the vagina or rectum.

An acute diverticulitis may require surgical treatment because of the effects of perforation into the general abdominal cavity, but recession of the inflammatory process is usual, and a large tender mass may disappear entirely. When symptoms of obstruction present, colostomy proximal to the obstructing mass is a good conservative method of handling the situation, with later resection of the mass if subsidence of the inflammation does not return a satisfactory lumen. In selected cases resection of the obstructed area with primary end-to-end anastomosis can be done. Because diverticulitis is an inflammatory process involving also the mesentery, surgical procedures must be handled with care.

Diverticula of the Colon as a Source of Bleeding. Only recently has diverticulosis or diverticulitis been accepted as a cause of bleeding from the rectum. Noer analyzed sixty-eight such cases at the Louisville General Hospital and found twenty to exhibit this finding (Fig. 526). Injection studies show the striking concentration of blood vessels in the region of the diverticula, their size and distribution within the wall of the diverticula being such as to make hemorrhage of varying degrees quite likely in the event of erosion or ulceration.

Surgery of Chronic Ulcerative Colitis. This serious inflammation should have thorough medical treatment for both its acute and

chronic form. Yet, in spite of the best to be offered, 15 per cent of the patients require surgical treatment because of (1) intractability to medical treatment, incapacity persisting for three months or more out of each year; (2) obstruction of the colon because of cicatricial change; (3) subacute perforations, abscesses, sinuses or fistulae; (4) persisting hemorrhage; (5) infectious arthritis; (6) polypoid change; (7) carcinomatous change.

Surgical treatment consists in an ileostomy to place the colon at rest, followed by continued general supportive management of the patient. A proper ileostomy requires that the mucosa be elevated above the skin, so that it can pour the irritating small intestinal contents into a snug-

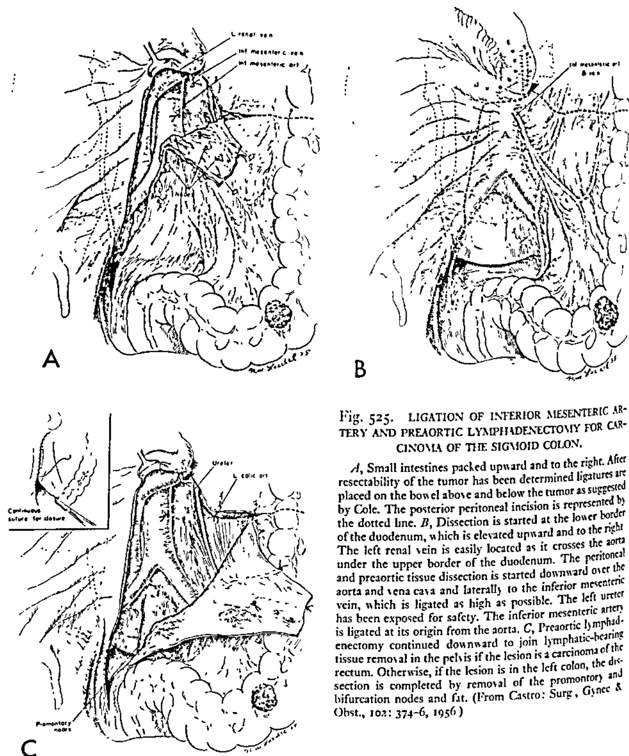


Fig. 525. LIGATION OF INFERIOR MESENTERIC ARTERY AND PREAORTIC LYMPHADENECTOMY FOR CARCINOMA OF THE SIGMOID COLON.

A, Small intestines packed upward and to the right. After resectability of the tumor has been determined ligatures are placed on the bowel above and below the tumor as suggested by Cole. The posterior peritoneal incision is represented by the dotted line. *B*, Dissection is started at the lower border of the duodenum, which is elevated upward and to the right The left renal vein is easily located as it crosses the aorta under the upper border of the duodenum. The peritoneal and preaortic tissue dissection is started downward over the aorta and vena cava and laterally to the inferior mesenteric vein, which is ligated as high as possible. The left ureter has been exposed for safety. The inferior mesenteric artery is ligated at its origin from the aorta. *C*, Preaortic lymphadenectomy continued downward to join lymphatic-bearing tissue removal in the pelvis if the lesion is a carcinoma of the rectum. Otherwise, if the lesion is in the left colon, the dissection is completed by removal of the promontory and bifurcation nodes and fat. (From Castro: Surg, Gynec & Obst., 102: 374–6, 1956)

Fig. 526. THE EXCELLENT BLOOD SUPPLY OF COLONIC DIVERTICULA, A SOURCE OF HEMORRHAGE FROM ULCERATION DUE TO INFLAMMATION OR TRAUMA.

Specimens of colonic wall prepared by clearing after injection of arteries and veins with red and blue latex. The diagrams indicate the location of the diverticula on the photographs. (After Noer: Ann Surg, 141: 674–85, 1955)

fitting glued-on colostomy bag, which is emptied as needed. Such patients may live a practically normal life. If healing of the colon occurs, as shown by sigmoidoscopy demonstrating a satisfactory appearance of the rectum and sigmoid, and barium enema revealing distensibility of the colon, the ileostomy can be undone. This is possible in very few of all ileostomy cases. For persistence of symptoms in the remaining 90 per cent, excision of the colon is indicated. Partial colectomy is used if there is a segmental distribution of the disease, and total colectomy if all the large bowel is involved. Total colectomy is usually done in two stages, first removing the terminal ileum, ascending, transverse and descending colon to the low sigmoid. At the second stage the lower sigmoid and rectum are excised. With patients in fair to good condition a one-stage ileostomy and resection of the colon and rectum can be done. All the aids of modern preoperative and



Fig. 527. HIRSCHSPRUNG'S DISEASE.

The sigmoid colon is thick-walled and tremendously dilated because of blockage due to the nonperistaltic rectosigmoid segment shown at the lower left. (From Swenson: Surgery, 28: 371–83, 1950.)

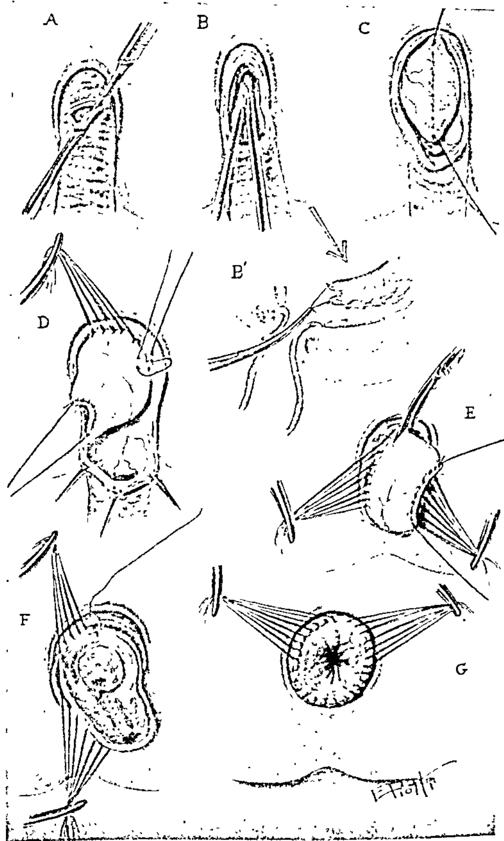


Fig. 528. PERINEAL PHASE OF ANASTOMOSIS OF DILATED COLON TO LOW RECTUM IN HIRSCHSPRUNG'S DISEASE.

The abdominal portion of the operation consists essentially in dividing the colon 12 cm. above the narrowed segment and mobilizing the proximal bowel so that it can be brought down to the low rectum. The upper part of the narrowed segment is removed and the lower part is pulled out through the dilated anal sphincters, as in *A. B*, The inverted low rectum, with

postoperative care are needed in these patients to keep the mortality rate low.

SURGICAL TREATMENT OF HIRSCHSPRUNG'S DISEASE. Idiopathic megacolon, or Hirschsprung's disease, occurs commonly in infancy and early childhood. The bowel is enormously enlarged, thick-walled and often elongated (Fig. 527). The sigmoid is most markedly affected, but the entire colon, including the rectum, is often involved. At one time the pathologic state was thought to be in the dilated portion of the colon, but now there is sound evidence of a developmental failure of Auerbach's plexuses in the narrowed distal segment, usually the rectosigmoid. Studies show a lack of propulsive peristalsis in these parts.

Swenson deserves great credit for developing the successful operative treatment of this disease, which consists in resecting the narrowed, malfunctioning, low bowel segment and anastomosing the dilated, functioning colon to the rectum 2 to 3 cm. above the mucocutaneous line (Fig. 528). In a short time the patients have normal sphincter control and one or two bowel movements daily.

Retroperitoneal Space and Contents

ILIOLUMBAR REGION

LUMBAR AND ILIAC FOSSAE. In the lumbar and iliac regions, between the peritoneum and the posterior parietal wall of the abdominal cavity, lie the contents of the retroperitoneal space.

On each side the *lumbar fossa* extends from the twelfth thoracic vertebra and twelfth rib to the base of the sacrum and the iliac crest. The lateral boundary is indicated by a vertical groove directed between the sacrospinalis and the flat abdominal muscles. Viewed from the abdominal aspect, after the contents of the space have been removed, the lateral margin of the region corresponds to the lateral border of the quadratus lumborum muscle. The floor of the space is formed by the quadratus lumborum and psoas major muscles, and extends from the lateral lumbocostal arch above to the iliolumbar ligament below. Both muscles of the floor have a definite fascial covering, that for the quadratus being derived from the lumbodorsal fascia as its anterior layer, and that for the psoas being directly continuous below with the fascia covering the iliacus muscle. These fascial layers are overlaid by a varying amount of fatty areolar tissue which fills the interstices between the muscles and furnishes a pliable bed for the superjacent viscera: the kidney, ascending colon, and duodenum on the right, and the kidney and descending colon on the left.

The retroperitoneal tissue is traversed by the ureter, renal vessels, spermatic vessels in the male, and ovarian vessels in the female. The tissue abuts against the inferior vena cava on the right and the aorta on the left.

The *iliac fossa* is overlaid by peritoneum, beneath which is a layer of retroperitoneal tissue directly continuous with that of the adjoining regions, the anterior and lateral aspects of the abdominal wall, the lumbar region above, and the pelvis below. Within the subperitoneal tissue of the iliac fossa are found the iliac vessels, ureter, genitofemoral nerve, spermatic or ovarian vessels, and the iliac lymph nodes. The iliacus muscle lies deep to the retroperitoneal tissue, separated from it by the iliac fascia. This fascia is continued upward over the psoas major muscle, is attached mesially to the linea terminalis or to the brim of the pelvis, and anteriorly to the proximal margin of the deep aspect of the inguinal ligament in its lateral half, where it fuses with the transversalis fascia (Fig. 364).

Surgical Considerations

ILIOLUMBAR ABSCESSES. The lumbar and iliac regions are of special interest in connection with certain forms of abscesses and their manner of extension. It is evident that there are two available sites for abscesses: within the extraperitoneal tissue, and beneath the iliac fascia and its extension over the quadratus lumborum and psoas major muscles (Fig. 529).

The commoner sources of abscesses *within the extraperitoneal tissues* are perinephric abscess, infected lymph nodes, lateral extension of a pelvic abscess which has originated in the areolar tissue of the broad ligament (perimetritis), more rarely the extension of infection from a retrocecal appendicitis, and occasionally

mucosa on the outside, is opened anteriorly. *B'*, Inserted forceps grasp the megacolon section and draw it down through the rectum, *C, D*, Approximation of the muscular coats. *E*, The proximal bowel is opened. *F*, The mucosae are now sutured together. *G*, The anastomosis is completed, sutures are cut, and the anastomosis line is allowed to retract up through the anus. (From Swenson: Surgery, 28: 371–83, 1950.)

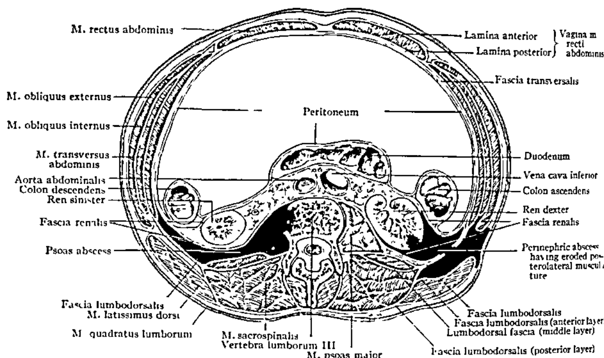


Fig. 529. CROSS SECTION TO SHOW EXTENSION OF ILIOLUMBAR ABSCESSES: PERINEPHRIC AND PSOAS ABSCESSES.

from the retroperitoneal duodenum and pancreas. The looseness of the areolar tissue and the laxity of the surrounding structures permit widespread diffusion of the infection.

Subfascial abscesses develop mainly from tuberculosis (caries) of the spine (Pott's disease). Pus from the diseased vertebral bodies is limited in its forward extension by the anterior longitudinal ligament of the spine. Its usual egress is directly into the body of the psoas muscle or between that muscle and its anterior sheath. An abscess in the thoracic region, or even higher, may gravitate down the posterior mediastinum and pass into the abdomen behind the lateral lumbocostal arch and enter the psoas compartment behind its sheath (Fig. 530). The purulent collection within the psoas sheath may destroy the muscle completely and occupy the entire compartment. Usually, with increasing amounts of pus, the subfascial space distends, and the abscess descends to the iliac fossa. Further distention causes pus to pass beneath the inguinal ligament at the lateral margin of the femoral vessels into the thigh, where it may follow one of a number of courses. Most frequently it passes down to the apex of the femoral triangle (of Scarpa), and points lateral to the femoral vessels at a point superficial to the attachment of the psoas tendon into the lesser trochanter. Sometimes the abscess appears to follow the femoral sheath to the origin of the femoral profunda artery, and then to follow the course of this vessel beneath the adductor longus muscle and subsequently to become superficial, forming a fluctuant swelling at the medial side of the thigh. Occasionally the abscess travels backward and points in the lumbar region, or it may seek an exit through the suprapiriform and infrapiriform foramina of the pelvis, pointing in the gluteal region along the course of the sciatic

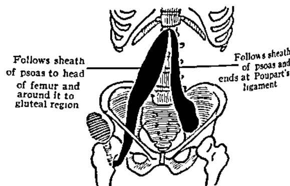


Fig. 530. PSOAS ABSCESS; VARIATION IN THE EXTENT OF SPREAD, DEMONSTRATED SCHEMATICALLY.

On the specimen's right the abscess, passing beyond the inguinal ligament with the iliopsoas muscle, points dorsalward in the gluteal region. On the left the abscess reaches the iliac fossa, stopping proximal to the inguinal (Poupart's) ligament.

nerve (Fig. 530). Pus may spread laterally, burst the psoas sheath, and fuse laterally on the iliacus muscle between it and its sheath, simulating an appendiceal abscess. If the iliac fascia is not strong enough to limit the abscess, pus may point on the skin near the anterior superior spine, where it may be evacuated extraperitoneally through a muscle-splitting incision. Infrequently, the pus may make its way backward along the course of the last dorsal or upper lumbar nerves, and point over the superior lumbar triangle or against the floor of the inferior lumbar triangle (of Petit). Usually, an extension is debarred from the pelvis by the firm attachment of the iliac fascia to the pelvic brim.

A well-developed psoas abscess may consist of a sinuous channel in the psoas muscle, an expanded area beneath the iliac fascia, a narrow neck beneath the inguinal ligament, and a lower expanded portion on the medial aspect of the thigh. The thigh is likely to be flexed because of irritation of the psoas muscle and the attempt to relieve muscle tension to prevent pressure on the lumbar nerves within the psoas sheath.

KIDNEY REGION

Adrenal Glands. The adrenal or suprarenal bodies are two small flattened glands of internal secretion comprised of a thin, but resistant, fibrous capsule and a cortical and medullary parenchyma. They are located in the upper median portion of each kidney fossa between the upper pole of the kidney and the great vascular trunks of the abdomen. The concave base of the gland rests upon the upper pole of the kidney like a cap; its posterior surface lies against the diaphragm, and its anterior margin extends toward the kidney hilum. On the anteromedian surface of the gland, chiefly, vessels enter and leave. In many cases, however, arteries enter the gland in radiating, spokelike manner, along its entire margin and over the anterior surface (Fig. 534, *a*).

Between the capsule of the adrenal body and the kidney is a layer of loose connective tissue admitting of easy separation of the kidney from the adrenal in nephrectomy. Both the kidney and adrenal lie within the perirenal fibrous capsule.

The arterial supply is regularly described as consisting of a superior suprarenal artery from the inferior phrenic, a small direct branch from the aorta, and an inferior suprarenal branch from the renal artery. While it is true that the suprarenal arterial supply is derived from the three sources just named, the conventional description errs profoundly on the side of simplicity. Not only are the arteries numerous (as many as sixty to a gland in some cases), but also they may be intimately associated with subdivisions of the main renal artery and with its branches. It is equally important to record that the venous plan does not match the arterial scheme. These features are described fully hereinafter (pp. 544, 548).

Kidneys. The kidneys are solid, glandular organs, one on each side of the spine opposite the twelfth dorsal and first three lumbar vertebrae. Because of the great size of the right lobe of the liver, the right kidney usually lies at a somewhat lower level than the left. Each organ is about 12 cm. long and 7 cm. broad. The middle of the mesial border of the kidney is hollowed out and constitutes the hilum, where the renal arteries and nerves enter, and the renal vein, the principal lymphatics of the organ and the ureter emerge (Figs. 531, 532). This hilar aggregate forms the *renal pedicle*. Because of the gradual increase in bulk of the psoas muscles as they descend, the inferior poles of the kidneys are directed forward and are wider apart than the upper poles.

The kidney is covered completely by a thin, but resistant, fibroelastic membranous *capsule*. Expansions of the capsule extend over the pelvis of the kidney and its excretory duct, the ureter. It is because of the solidity and tenacity of its investing membrane that the otherwise friable kidney bears suturing. Even when the parenchyma is destroyed by infection, the capsule usually resists destruction. Inversely, it may constrict and strangulate the organ in an acute nephritis; hence the procedure of capsular decortication to relieve parenchymal congestion. Normally, the capsule is connected loosely to the kidney parenchyma by delicate vascular connective tissue, and can be stripped away readily.

The kidney hilum expands into a central cavity, the *renal sinus*, which contains the uppermost and expanded part of the kidney pelvis and calices. The kidney parenchyma consists of an inner medullary and an outer cortical substance. The *medulla* is composed largely of a number of conical pyramids. These are arranged with their bases directed toward

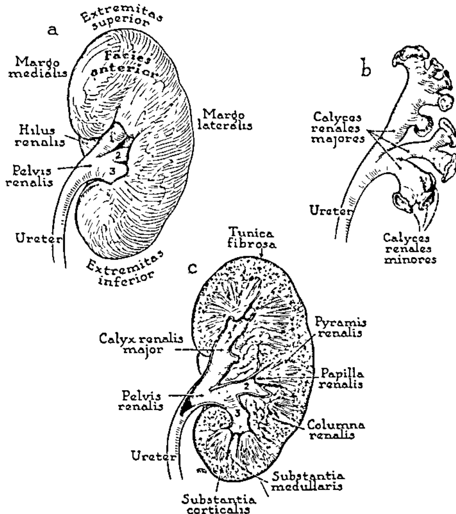


Fig. 531. KIDNEY AND URETER: EXTERNAL FORM AND INTERNAL STRUCTURE.

a, The kidney, renal pelvis and proximal portion of the ureter; anterior surface. *b*, The renal pelvis and calices. *c*, The structure of the kidney, seen in section. The major calices are numbered to correspond with the enumeration in *a*.

the surface and their apices toward the renal sinus, where they form prominent papillae which project into the interior of the calices (Figs. 531 to 533). The bases of the pyramids do not reach the surface of the kidney, but are separated from it by a thin layer of kidney substance, the *cortex*. The cortical substance not only covers the bases of the pyramids, but also sends prolongations, called renal columns, between the pyramids toward the sinus. The medullary part of the kidney in section is striated, while the cortical part is granular and usually different in color. The larger blood vessels lie between the pyramids (Fig. 532).

At its proximal extremity the ureter widens into a funnel-shaped sac, the *renal pelvis* which is contained, for the most part, within the renal sinus behind the vessels (Fig. 532). As a rule, the extrarenal portion of the pelvis, that projecting beyond the kidney sinus, is larger than the intrarenal part. However, the whole pelvis may lie within the renal sinus and be invisible at the kidney hilum. The renal vessels regularly lie anterior to the pelvis on each side (Figs. 535, 536); only occasionally do branches of the vein and artery lie on the dorsal aspect.

The renal pelvis lies among the larger renal vessels and is formed usually by the junction of three thin-walled tubes, the superior, middle and inferior *major calices;* occasionally there may be only two major calices. Into each major calix open a number of smaller or *minor calices* (Fig. 533). Their wide, somewhat funnel-like ends enclose the renal papillae and receive the urine. When the kidney pelvis is small and consists only of the major calices, there is no extrarenal pelvis, and a stone can be removed only by incising through the kidney substance.

VESSELS. The traditionally simple form of renal pedicle commonly portrayed in standard

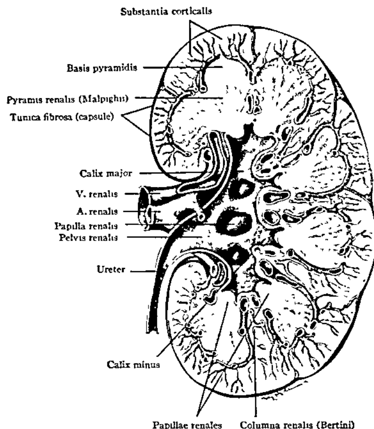


Fig. 532. FRONTAL SECTION THROUGH THE KIDNEY.



Fig. 533. CASTS OF TYPES OF THE HUMAN RENAL PELVIS, SHOWING MAJOR AND MINOR CALICES. Actual size and capacity.

anatomy texts cannot be accepted in the light of critical study of the kidney area. The renal vascular elements are not isolated from the blood vessels of neighboring regions. Instead, the kidneys receive numerous arteries from varied sources, and venous tributaries converge upon them from both adjacent and remote visceral and parietal structures, thereby providing a remarkable complexity of pattern and vascular interrelationships (Figs. 534, *a*; 537). The intimate association of these vessels is of particular clinical interest, since those of even small caliber may become important conduits when they serve as collateral pathways. This accommodation to additional blood volume in pathologic processes is often facilitated

by the persistence, in the postnatal body, of developmentally transitional channels. Because the kidneys develop in a richly plexiform vascular bed, variations in arterial supply and venous drainage would be anticipated (Figs. 534 to 538).

The fallacy of the concept of the renal pedicle is heightened by a consideration of the combined renal and suprarenal arterial supply; topographically, they cannot be separated (Fig. 534, *a*, *b*). Together, these sets of vessels often cover a quadrilateral vascular field whose vertical dimension may exceed that of the kidney itself. Supernumerary renal vessels of large size are common, being derived from the aorta as serially arranged stems. Smaller ones to the hilus or to the renal parenchyma (that is, extrahilar rami) are commonly branches of arterial stems which are also suprarenal. Supernumerary renal arteries, large and small, are also derived from the internal spermatic and supe-

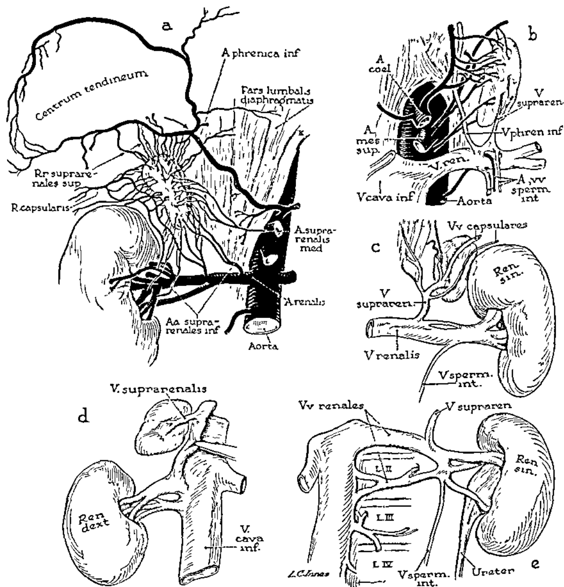


Fig. 534. RENAL, SUPRARENAL AND RELATED BLOOD VESSELS.

a, Renal and suprarenal arteries, demonstrating especially the abundant supply to the adrenal gland. *b*, Suprarenal arteries derived chiefly from 2 inferior phrenic arteries. The internal spermatic artery passes through a hiatus in the renal vein. *c*, Typical tributaries of the left renal vein. The internal spermatic joins the renal vein caudally, while the suprarenal (with tributaries, in turn, from the diaphragm and capsule) enters the renal vein cranially. *d*, Typically short right suprarenal vein, tributary to the inferior vena cava, combined with double renal vein. *e*, Complex arrangement of the renal veins of the left side. Three polar tributaries converge; then the divisions of the conjoined trunk, as elements of a so-called circumaortic venous ring, surround the aorta (the latter vessel excised). The inferior, retroaortic limb receives a lumbar vein. (From Pick and Anson: Anat. Rec., 78: 413-27, 1940; Anson, Cauldwell, Pick and Beaton: J. Urol., 60: 714-37, 1948.)

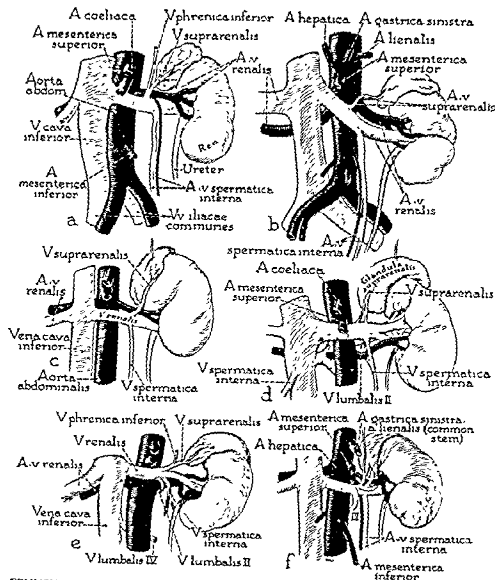


Fig. 535. COMMON VARIATIONS IN THE RENAL BLOOD SUPPLY. SELECTED EXAMPLES FROM A STUDY OF 33 CONSECUTIVE LABORATORY SPECIMENS.

a, The most frequent arrangement of renal tributaries, in which the inferior phrenic and suprarenal veins (combined in a common vessel) and the internal spermatic vein enter the left renal; and in which the vessel which terminates on the caudal (inferior) border of the transversely coursing renal vein is situated lateral to the point at which the confluent stem enters on the cranial (superior) border. The internal spermatic artery is unusual in accompanying the renal vessel in the medial half of the pedicle. *b*, The suprarenal vein enters the renal independently, and left internal spermatic artery arises at the usual level. In the presence of these common features a rare arterial variation occurs in which the 3 vessels regularly derived from a celiac axis take origin independently *from* the aorta. *c*, The regular tributaries enter the renal vein opposite each other. *d*, The suprarenal and internal spermatic veins are bifid, the latter sends its divergent channels into the renal vein on superficial level and into the second lumbar vein on deep level. The renal artery courses between the arms of the Y-shaped division. *e*, The second left lumbar vein ends independently in the renal, but the fourth lumbar crosses to the opposite side to become a caval tributary. *f*, The third left lumbar vein ends in the renal, the suprarenal vein is double, one of the pair being confluent with the inferior phrenic. On the arterial side the left gastric and splenic arteries arise from a common aortic stem, while the hepatic (in the absence of a celiac source) leaves the aorta independently. An accessory renal artery arises as a common stem with the internal spermatic, both becoming constituents of the renal pedicle. (From Anson and Kurth: Surg., Gynec. & Obst., 100: 156-62, 1955.)

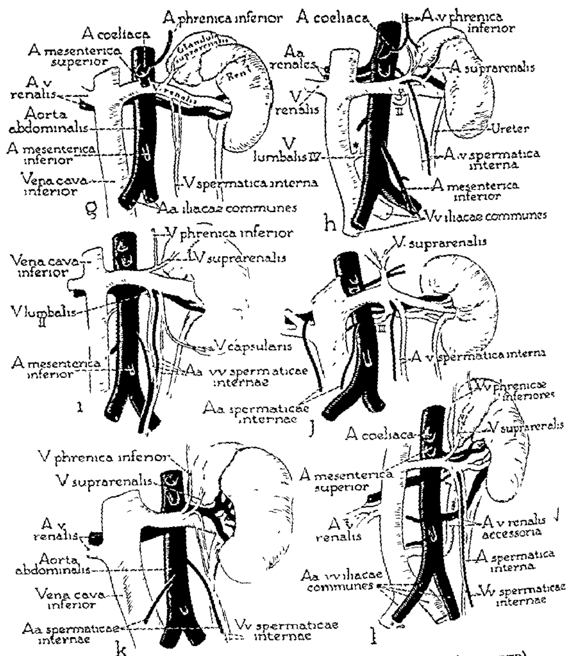


Fig. 536. COMMON VARIATIONS IN THE RENAL BLOOD SUPPLY (CONTINUED).

g, Bifurcation of the internal spermatic vein, the separate channels entering the renal lateral to the point of terminatio
of the suprarenal vein. *h*, The left renal vein divides. An internal spermatic artery of high origin passes through the hiat
thus formed, to become a constituent of the renal pedicle The cranial element of the divided vein receives a supraren
tributaries, one of which is confluent with the inferior phrenic vein, while the caudal division receives a large second lumb
and an internal spermatic vein. One of the lower lumbar veins receives lesser tributaries from prevertebral level (at *). *i*, O
its caudal margin the left renal vein receives the divisions of a bifid internal spermatic (the lateral one of the pair being
common tributary with a capsular vessel) and the second lumbar vein The spermatic artery is also double in the upper po
tion; the cranial one of the pair, being renal in origin, emerges from the pedicle. *j*, Doubling of the left renal vein through t
lateral half of its course; the superficial limb receives the visceral tributaries (suprarenal and internal spermatic), the dee
limb receives the parietal tributary (third lumbar vein). The left internal spermatic artery, after a short transverse course as
a constituent of the renal pedicle, hooks around the Y-shaped confluens of the renal limbs to descend vertically with the
corresponding vein. On the right side an internal spermatic artery of aortic origin gives rise to a lumbar vessel; the other
arising from the renal, arches over the renal vein *k*, One of a pair of internal spermatic veins enters the left renal vein inde-
pendently; the other forms a common channel with the suprarenal. *l*, One of a pair of inferior phrenic veins joins the supra-
renal in the customary way; the other courses through the gland before establishing connection with the suprarenal drainage
Caudally the tributaries are elements of, or vessels related to, an elongate type of so-called circumaortic venous ring. The
postaortic limb of the "ring" (serving as an accessory renal vein and matching the course of a supernumerary artery) joins the
preaortic limb just as the latter receives 2 internal spermatic veins and a single second lumbar vein. Additionally, an internal

rior mesenteric arteries; additionally, when the kidneys are ectopic or fused, they may arise from the iliac, hypogastric and middle sacral arteries. Such accessory renal arteries are usually numerous at the superior extremity (upper pole) of the kidney, since many of them are primarily suprarenal (Fig. 534, *a*).

The adrenal glands are abundantly supplied (Fig. 534, *a*, *b*). They receive rami from several sources, each being the focus for many convergent vessels. From above, rami descend from the inferior phrenic; medially, they cross from the aorta; from below, twigs ascend from the renal artery and its hilar divisions. Altogether, as many as sixty rami sometimes reach an individual adrenal gland. Although the renal and suprarenal arteries are intimately interrelated, there is no similarity in pattern between the two sets.

Dissimilarity obtains, too, between the suprarenal veins of the two sides—or, rather, similarity is limited to the occurrence, on each side, of a single venous channel. On the left side the suprarenal vein enters the renal as a channel of a vertical course, usually confluent with the phrenic vein (Fig. 534, *c*). On the right side the suprarenal vein is much shorter, independent of other neighboring vessels, caval in termination and oblique in its course (Fig. 534, *d*). Its singleness stands in striking contrast to the multiplicity of suprarenal arteries.

Comparably, the renal venous pattern of the right side bears little resemblance to that of the left. In its relatively short course from the kidney to the inferior vena cava, the right renal vein rarely receives a tributary (Fig. 534, *d*). When a venous channel does enter the renal, it is the gonadal vein (spermatic or ovarian), not—except when the aorta and vena cava are transposed—the lumbar or the suprarenal. The longer left renal vein, on the contrary, regularly receives the following tributaries: suprarenal and inferior phrenic, from above, frequently by a common or confluent channel (Fig. 534, *c*); spermatic (or ovarian) and second or third lumbar veins from below, likewise often by a confluent vessel. Reception of these tributaries is a result of passage of the left renal across territory occupied by the left adrenal gland, primordially by the testis or ovary, and by lumbar veins, which, on the opposite side, drain directly into the inferior vena cava. In cases of complete situs inversus the longer right renal vein, in crossing the corresponding psoas major muscle and the vertebral column, receives tributaries which, in normal cases, terminate on the left side in the left renal vein.

In a preponderant number of specimens there is a single renal vein on the right side. Sometimes, however, there are two or even three veins (Figs. 534, *d*). When present in duplicate or triplicate, the veins are approximately equal in caliber and parallel in course; rarely do adjacent channels anastomose.

As might be expected, on the basis of its posterior relationships, the left renal vein is complex, not only in arrangement of its tributary system, but also in its pattern of division and anastomosis. Thus, while the term "pedicle" is somewhat appropriate for the set of blood vessels which enter and leave the right kidney, it is rarely suitable for the congeries of channels on the left side (Figs. 535 to 538). In many specimens, on the left side, in preaortic position, the veins from the kidneys, which are constituents of the so-called renal pedicle, seem to be relatively simple in arrangement; on each side, that is, there is likely to be a single renal vein in front of the aorta. However, on the retroaortic, or prevertebral, level, complexity in venous pattern occurs; the retroaortic members of the plexus regularly communicate with lumbar veins, and the retroaortic set of veins is often associated with the deeper division of a circumaortic venous ring (Figs. 534, 537). The preaortic vein then receives the suprarenal vein, while the retroaortic veins communicate with veins draining the prevertebral connective tissue, and with lumbar veins. Usually the retroaortic element of the ring is oblique, joining the left renal vein near the hilus of the kidney; but in rare instances the tributary is transverse and enters the parenchyma of the lower pole of the kidney. Here it is likely to receive iliac and lumbar veins before reaching the inferior vena cava.

The direct lumbar tributary of the left renal vein is typically a single trunk which traverses a short distance between the point at which it emerges from the psoas muscle and that at

spermatic artery loops around the lumbar tributary. The pedicle is exceptionally long (10 cm.) and consists of the following vessels: 3 renal arteries, 2 renal veins; 3 internal spermatic vessels (2 veins, 1 artery); a lumbar vein; a combined vessel formed by meeting of the suprarenal and inferior phrenic veins. (From Anson and Kurth: Surg., Gynec. & Obst., 100: 156–62, 1955.)

which it meets the vein from the kidney; occasionally doubling of the lumbar tributary occurs. The scheme of lumbar drainage varies widely, but there is a tendency toward concentration of the tributaries toward the upper lumbar (that is, renal) level on the left half of the body. The left ascending lumbar may be complete (Fig. 538, *a*, *b*), interrupted (Fig. 538, *c*), gain caval communication by double veins (Fig. 538, *a*) or by indirect, paravertebral connections (Fig. 538, *b*, *c*). Variation may also be expressed in any one of the following ways:

A single lumbar vein, either the first or second, enters the renal; the first and second lumbar veins enter the renal independently or by a common trunk; the first or second lumbar vein first joins a hemiazygos tributary (of lumbar origin) before emptying into the renal; the second or third lumbar vein (one or both, independently or by common trunk) joins with the genital vein before terminating in the renal; a series of lumbar venous tributaries join a long vertical trunk, the persistent left inferior vena cava, before entering the renal.

In addition, on the left side the channels of the capsular network often form a circumrenal venous network whose constituents drain directly or indirectly into the renal veins. These are not simply retroperitoneal channels. The cranial set of capsular veins often receive muscular tributaries (from diaphragm, psoas major, quadratus lumborum), as well as lower suprarenal and phrenic tributaries, before emptying by multiple veins into the renal; the inferior set may receive one or more lumbar veins, usually indirectly; a caudal portion of the capsular system frequently joins the genital vein before entering the renal.

Dorsal parietal veins emerge through the quadratus muscle to enter the confluens of the lumbar and ascending lumbar veins; dissections reveal that this site is also the point at which the vein is recipient of tributaries from the vertebrae, meninges and spinal cord. By this means the axial musculature, skeletal elements and central nervous system are brought into direct venous connection with the kidneys.

Vascular complexity, common in the left renal area, is sometimes increased by the occurrence of a left inferior vena cava in association with a circumaortic venous ring (Fig. 537, *a*, *b*). Two caval channels then exist side by side, brought into communication cranially by the postaortic element of the venous ring and caudally by the left common iliac vein. A third vertical channel is commonly present, in the form of an ascending lumbar vein *en route* to the hemiazygos vein.

When the usual communications of the left renal vein are grouped, as if the observer were viewing a composite of three or four selected specimens, the true expanse of the renal field of vascular influence becomes apparent. The left renal vein is then found situated at the core of an impressive set of venous plexuses and veins: inferior phrenic and suprarenal tributaries enter from above; from below and the side come spermatic (or ovarian), capsular, lumbar and ascending lumbar veins and anomalous vena cava. Additionally, communication is made with azygos and hemiazygos veins (usually through lumbars) and with the extensive set of internal and external vertebral plexuses by way of intervertebral and lumbar veins These widespread connections bring the following structures into venous relationship with the kidney: the respiratory diaphragm; the adrenal gland, testis, ductus deferens and ureter; the capsular and the general retroperitoneal tissue; the peritoneum; the lumbar, dorsal axial and appendicular muscles (psoas major, sacrospinalis, quadratus lumborum, latissimus dorsi and trapezius); the superficial fascia and skin; the ribs, intercostal muscles, thoracic subserous tissue; the pleura and pericardium; the vertebrae, their disks and ligaments; the spinal cord and its meningeal coats; the viscera, musculature and skeletal elements of the pelvis; and the lower extremities.

Regarding renal arteries, it may be said in summary that, when large, they are sometimes single on each side; common, however, is the condition of doubling or trebling, on one or both sides, the multiple vessels having approximately equal caliber. In addition to the larger vessels with which textbooks have made readers familiar, numerous small vessels pass to the superior extremity of the kidney. Such arteries usually are not solely renal in supply, but care also for part of the vascularization of the adrenal gland. These arteries of combined renal and suprarenal termination ordinarily represent a lesser portion of the total number sent to the adrenal gland—the greater number being derived from the inferior phrenic, augmented by vessels of direct aortic origin. In general terms, it may be said that the arterial supply of the kidneys and adrenal glands of the opposite

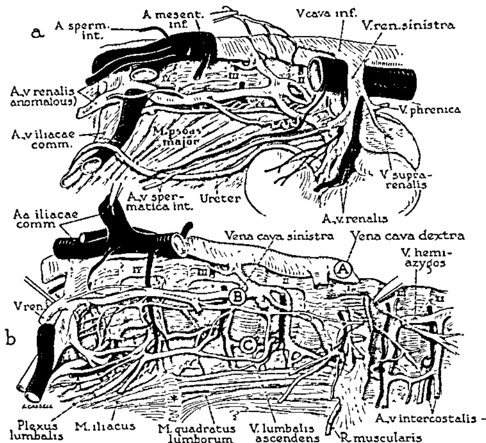


Fig. 537. RENAL VENOUS COMMUNICATIONS, PARIETAL (LUMBAR) AND VISCERAL.

In this specimen a pelvic kidney occurred on the right side, and a circumaortic venous ring and persistent caval channel on the left. From the aorta, in *a*, a segment has been excised to expose the postaortic limb of the ring. In *b* the left kidney and portions of both venous limbs have been removed; the psoas major muscle has been dissected away. In *a* the arrow points to an accessory loop of the left inferior vena cava, which passed ventral to the common iliac artery. In *b* the asterisk marks the crest of the ilium. *A*, Inferior vena cava; *B*, persistent left vena cava; *C*, ascending lumbar vein.

The ascending lumbar vein is connected with the left inferior vena cava by segmentally arranged lumbar veins. The latter are brought into connection with the azygos vein system through the intermediation of a trunk which passes behind the diaphragm. Here the 3 vertical venous channels occur: a large right inferior vena cava, a smaller left, and an intramuscular ascending vein. The ascending lumbar vein is in close proximity to the nerves of the lumbar plexus. The renal vein divides to form a circumaortic venous ring; the deep division receives the left inferior vena cava and communicates with the hemiazygos vein. (From Anson, Cauldwell, Pick and Beaton: Surg., Gynec. & Obst., 84: 313–20, 1947; J. Urol., 60: 714–37, 1948.)

sides of the body is fundamentally similar; vessels are numerous, they have like sources, and they may assume comparable patterns as they pass from parent vessels to the viscera mentioned.

Regarding veins, it must be emphasized that dissimilarity governs the patterns of the right and left sides, that veins (as compared with arteries) are few, and that complexity (a feature of the left side only) is the result of venous intercommunication, and not of multiplicity of channels. On the right side the single suprarenal vein, in surprisingly short course, and uncomplicated by reception of tributaries, empties into the inferior vena cava; the right renal is short, seldom split or doubled. On the left side, where again it is seldom paired, the suprarenal vein almost always receives the inferior phrenic *en route* to the left renal vein. It also receives capsular tributaries. Of the four veins (renals and suprarenals), the left renal is by far the most complex in its scheme of tributary reception and its pattern of venous communication. It receives, at least, the suprarenal and phrenic (separately or as a conjoined trunk), the internal spermatic or the ovarian vein. Additionally, it often receives capsular tributaries, directly or indirectly (by the suprarenal vein, as an intermediary). Frequently it communicates with lumbar veins even when it is single.

which it meets the vein from the kidney; occasionally doubling of the lumbar tributary occurs. The scheme of lumbar drainage varies widely, but there is a tendency toward concentration of the tributaries toward the upper lumbar (that is, renal) level on the left half of the body. The left ascending lumbar may be complete (Fig. 538, *a*, *b*), interrupted (Fig. 538, *c*), gain caval communication by double veins (Fig. 538, *a*) or by indirect, paravertebral connections (Fig. 538, *b*, *c*). Variation may also be expressed in any one of the following ways:

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tion is reinforced by the pancreas, which is applied over it.

The transversalis fascia splits into prerenal and retrorenal fascial layers at the lateral border of the kidney and forms a fascial compartment known as the *perirenal fascial space* (of Gerota), which incloses both the kidney and the adrenal gland (Fig. 540). A loose layer of connective tissue separates the two organs in such a manner that the kidney may be dislocated dorsally, while the adrenal gland remains in place. The compartment is open mesially where the anterior (prerenal) and the posterior (retrorenal) layers are continued across the median line. The compartment is in broad communication below with the extraperitoneal tissue of the lumbo-iliac region. Superior and lateral to the kidney, the layers are approximated. Below the lower pole of the kidney the layers remain spread apart for a distance, affording an anatomic cleavage area predisposing to movable kidney. Where the primitive ascending and descending portions of the mesocolon have fused with the primitive parietal peritoneum, a fusion fascia (of Toldt) is formed; it reinforces the subjacent prerenal leaf of fascia. The retrorenal fascia overlies the quadratus lumborum and psoas muscles and is very resistant.

Between the posterior layer of the perinephric fascia and the transversus abdominus aponeurosis lies the *retrorenal (pararenal) fat*, which is a portion of the extraperitoneal fat pad lying behind all the abdominal contents. It is continuous with the extraperitoneal fat of the anterolateral and posterior abdominal walls and with the extrapleural areolo-adipose tissue above the edges of the diaphragm. The amount of pararenal fat varies from a layer 5 mm. thick to a cushion of enormous dimensions, upon which the perirenal fascial space and the fatty tissue rest.

Within the fibrous envelope of the kidney is the *perirenal fat capsule* or *tunic*, a specialized fatty tissue designed to hold the kidney and its pedicle *in situ*. The fat is more abundant along the borders of the kidney and behind it than in front. Its almost fluid consistency allows the kidney to execute the normal movements transmitted to it by the diaphragm. The fat passes into the hilum and insinuates itself between the renal blood vessels, affording them protection; it fuses with the outer coat of the calices. Deli-

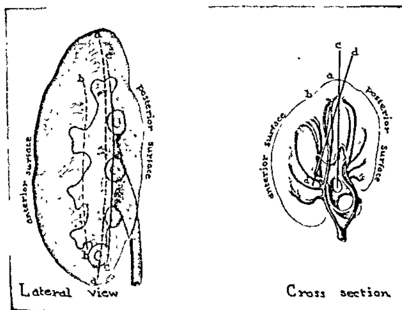


Fig. 539 SIDE VIEW AND CROSS SECTION OF THE KIDNEY TO SHOW THE PROPER PLANE FOR INCISION: BRÖDEL'S LINE.

Line *a-a* represents the periphery of the convex border. An incision along the line *b-b* would sever many vascular trunks and should be avoided. Brödel's line, *c-c*, lies at approximately the junction of the posterior and middle thirds of the kidney, and is a relatively avascular plane along which incision through the kidney should be made. The hemorrhage encountered can be controlled by pressure on the vascular pedicle. Line *d-d* indicates an incision not in the frontal plane, and one which, if continued, will cut through the large vessels in the depth of the kidney. (From Kelly, Burnam.)

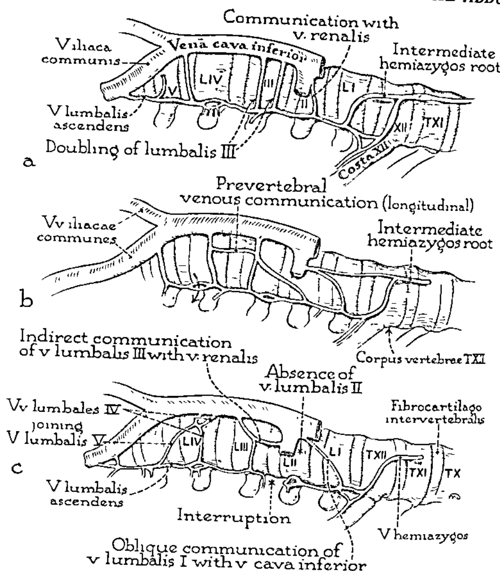


Fig. 538. ASCENDING LUMBAR VEIN OF THE LEFT SIDE, WITH CAVAL, RENAL AND AZYGOS COMMUNICATIO

Types encountered in a study of 81 specimens.

a, Caval communications at 3 lumbar levels and thoracolumbar connection with the hemiazygos vein. *b*, Accessory longitudinal connection in paravertebral position and direct connection between the renal and hemiazygos veins. *c*, Retroaortic renocaval arch, obliquely coursing lumbocaval channel and interrupted ascending lumbar vein. Frequently the ascending lumbar vein forms a circumneural "ring" (at arrow in *b*) around a lumbar nerve. (From Davis, Milloy and Anson: Surg Gynec. & Obst., in press.)

When subdivided, to send divisions in annular fashion round the aorta, the left renal veins receive lumbar and other tributaries of azygos and related drainage. When a persistent left inferior vena cava is present, renal communications are established therewith.

There are superficial and deep LYMPHATIC SYSTEMS in the kidney. The superficial system drains the fat capsule about the kidney and the true renal capsule. The deep system drains the parenchyma. The vessels of both systems are afferent to lymph nodes located, for the most part, behind the pelvis at the hilum. These nodes are involved in renal carcinoma. Spread of carcinoma into the left renal vein may involve the left spermatic vein, with resulting varicocele. Efferent vessels from the renal lymph nodes drain to the lumbar lymph nodes along the aorta and inferior vena cava.

FIXATION OF THE KIDNEY; PERIRENAL FASCIA; RETRORENAL AND PERIRENAL FAT. The kidneys in their niches in the hypochondria are maintained in position against the posterior abdominal wall by a variety of mechanisms; they are held in place chiefly by the fascial and fatty structures lying about them, partly by the attachment of the renal pedicles, and partly by intra-abdominal pressure. The left kidney posi-

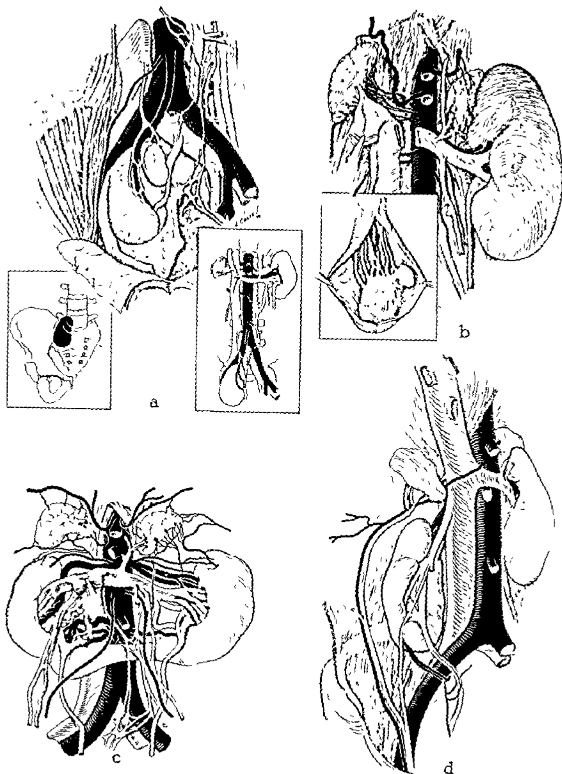


Fig. 541. RENAL ANOMALIES.

a, Pelvic kidney, right side. Insets. Position of the kidney in relation to the sacroiliac articulation and vertebral column; kidneys and adrenal glands and the related blood vessels *b*, Renal agenesis on the right side. Inset: Associated atrophic testis of the same side. *c*, Fused, or so-called horseshoe, kidney. *d*, Iliolumbar kidney, right side. (From Anson, Pick and Cauldwell: J. Urol., 47: 112-32, 1942; Daseler and Anson: J. Urol., 50: 155-63, 1943; Anson and Riba: Surg., Gynec. & Obst., 68: 37-41, 1939.)

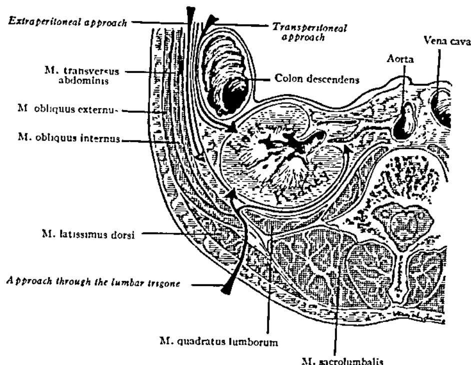


Fig. 540. CROSS SECTION TO SHOW THE PATHS OF APPROACH TO THE LEFT KIDNEY.

cate fibrous septa pass from the perirenal fascia to the true kidney capsule and loculate the fatty tissue. The more fat present, the more rigidly the kidney is held in position. Lesions of the perirenal tunic occur in perinephritis.

Relations of the Kidney to the Vertebrae, Diaphragm and Pleura. The upper pole (superior extremity) of the kidney lies almost at the level of the middle or lower portion of the eleventh or twelfth thoracic vertebra, while the inferior pole (inferior extremity) extends as low as the body of the second or third lumbar vertebra. Extension beyond these points is abnormal. The right kidney usually is placed 1 to 2 cm. lower than the left, because the large right lobe of the liver arrests its ascent. The kidneys generally lie about half the thickness of a vertebra lower in females than in males. In early childhood the kidneys lie at a definitely lower level than at any subsequent time because of their relatively greater size and the relatively shorter lumbar region. A line connecting the tips of the lumbar transverse processes marks the median border of the kidney.

About one fourth of the right kidney and one third of the left lie in contact with the diaphragm. If there are weak portions in the opposing areas of diaphragm, the posterior surface of the kidneys may come into close relation with the pleura. Weak areas in the right diaphragm are protected, in a large measure, by the right lobe of the liver, which may explain the small number of right perinephric abscesses pervading the diaphragm and causing pleural empyema.

The posterior costodiaphragmatic pleural reflections divide the kidneys into covered and uncovered areas. The reflection of the posterior costal pleura to the diaphragm occurs along a horizontal line beginning at the lateral surface of the twelfth thoracic vertebra on the same level as, or a little below, the origin of the twelfth rib, and passes obliquely downward and laterally. The twelfth rib crosses the reflection about three fingerbreadths lateral to the median line, so that the proximal 4 cm. of the rib lie above the level of the pleura, while the distal portion extends below it. Irrespective of the length of the rib or its absence, the lower line of pleural reflection remains the same; for this reason it is important to know whether the last palpable rib is the eleventh or twelfth. This is determined by counting from above downward. About half of the left kidney and one third of the right lie above the pleural line, the left kidney being the higher placed. In renal surgery, production of an artificial pneumothorax may be prevented by observance of the natural protection afforded the pleural reflection by the lumbocostal ligaments externally and the lumbocostal arches intra-abdominally.

Renal Anomalies. Congenital variations of

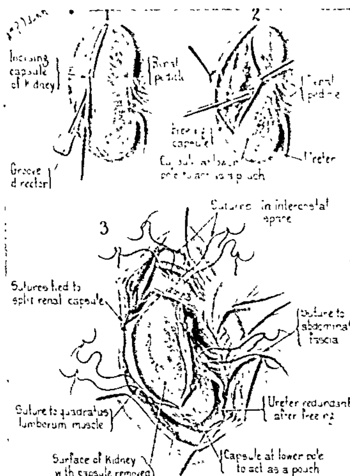


Fig. 542. CABOT'S TECHNIQUE OF NEPHROPEXY.

1 and 2, The kidney capsule is incised over a groove director, and the capsule is stripped up to form flaps. The capsule ot the lower pole is left intact as a suspensory pouch. 3, Four sutures are placed in the capsular flaps. The 2 upper sutures are passed beneath the twelfth rib and through the intercostal muscle. When tied, these upper sutures will bring the upper pole of the kidney above the level of the eleventh rib. The 2 lower sutures are fixed to the quadratus lumborum muscle and abdominal fascia. The perirenal fascia and fatty capsule will be brought across the lower pole of the kidney and also sutured to the quadratus lumborum muscle. This cushion of fat and fascia creates new adhesions and aids in maintaining the kidney in its suspended position. (From Cabot: Modern Urology, Philadelphia, Lea & Febiger.)

hydronephrosis (Fig. 544). When marked infection occurs in the hydronephrotic sac, the condition becomes one of *pyonephrosis*.

Blockage to the urinary outflow may occur anywhere in the ureter or urethra, and distention may occur in the calices or pelvis alone, or in both these portions of the excretory system. Retentive phenomena may be caused by an abnormal position of the kidney or by an aberrant vessel which kinks the ureter.

PERINEPHRITIC ABSCESS. An abscess in the perirenal space (Fig. 529) occurs by infection through the blood supply, by extension of infection from the kidney itself (Fig. 544) or by contiguity from adjacent structures. When extensive, it is hard to differentiate from a psoas abscess (Fig. 530). A large group of perinephritic infections is secondary to pyogenic skin conditions, the usual organism being the staphylococcus, and the alleged course being a small, superficial acute or subacute cortical kidney abscess that ruptures and infects the perirenal fatty-areolar tissue. Urinary findings in such circumstances are usually within normal limits. Pain, if present, radiates along the course of the twelfth intercostal nerve and the iliohypogastric and ilio-inguinal branches of the first lumbar nerve. Roentgenologic examinations of the lumbar and lower dorsal regions may show certain diagnostic signs: obliteration of the psoas muscle shadow, or marked dullness of its ordinarily sharp contour; obscuring of the kidney outline

the kidneys are relatively infrequent. In a study of 500 consecutive anatomic specimens* a single example each of pelvic kidney (Fig. 541, *a*) and renal agenesis (Fig. 541, *b*) was encountered; three examples of fused kidney were observed (Fig. 541, *c*), and two of iliolumbar kidney (Fig. 541, *d*).

Surgical Considerations

MOVABLE KIDNEY. Being closely applied to the arch of the diaphragm, the normal kidneys move downward in respiration through an excursion of about 2 cm. An excessive range of mobility is encountered rather frequently, especially in women. Because of the displacing effect of the liver, the right kidney is mobile much more frequently than is the left.

Several problems present themselves in the consideration of a movable kidney: first, demonstration of the mobility; second, evaluation of the symptoms arising from the condition; and, third, treatment. The displaced kidney can often be detected by abdominal examination, one hand being placed in the costo-iliac space posterior and lateral to the sacrospinalis muscle, and the other laid flat upon the subcostal abdominal wall lateral to the semilunar line. On deep inspiration a movable kidney may be felt as a smooth, rounded body well below the costal arch, where it may be held between the thumb and forefinger. If an effort be made to compress its lower extremity, it usually slips upward out of reach and reappears when the patient stands or inspires deeply. The importance of palpating the movable kidney with the patient lying upon the opposite side and in the sitting and standing positions, as well as the recumbent, should be emphasized.

A movable right kidney must not be confused with a large gallbladder. On either side, an ovarian cyst with a long pedicle may simulate a movable kidney, as the tumor may be manipulated into the position normally occupied by the kidney. The discomfort in movable kidney probably results from tension on the peritoneum and on the renal nerve plexuses passing to and emerging from the kidney pedicle. The pain is referred to the abdominal wall along the sensory nerves derived from the tenth thoracic to the first lumbar segment.

Correction of this condition requires fixing the kidney in its normal position and maintaining it by nonoperative or operative measures. Nonoperative treatment consists in application to the abdomen of variously devised supports and belts, and attempts to fatten the patient. These procedures are usually unsatisfactory. Operative treatment (nephrorrhaphy or nephropexy) consists in fixing the kidney in its normal fossa. Numerous procedures have been devised for this purpose, a common one depending upon suturing the kidney into the muscles at about the level of the twelfth rib (Fig. 542).

INJURIES OF THE KIDNEYS. Severe contusions and penetrating wounds of the kidney are minimized by the deep position of the organ and its protection by the lower costal margin and the viscera applied against its abdominal aspect. Since the eleventh and twelfth ribs rarely are fractured, kidney laceration from direct impact of broken ribs seldom occurs. Rupture may occur from hydrostatic pressure from impact of the twelfth rib. Contusions sufficiently serious to injure the kidney usually are received in the iliocostal space, and are likely to cause more serious injury if the abdominal walls are relaxed at the moment of impact. The kidney is pushed back and is wedged tightly into the costovertebral angle, and may be crushed against the last rib and the upper two lumbar vertebrae.

Kidney rupture may be incomplete, the cortex and parenchyma only being lacerated; or it may be complete, and extend from the exterior to the interior of the organ, from the capsule into the pelvis. Most injuries of the kidney are incomplete, and operation is not indicated except to care for delayed complications. The tear may involve the overlying peritoneum and result in serious intra-abdominal hemorrhage. In complete rupture an extravasation of blood and urine may spread diffusely into the perirenal tissue and give rise to a large extraperitoneal extension which may bulge the flank and pass downward into the iliac fossa. In these instances prompt nephrectomy is indicated as a lifesaving procedure.

HYDRONEPHROSIS. Hydronephrosis or, perhaps better, uronephrosis designates urinary retention in a distended kidney pelvis and its calices, resulting from some impediment to urinary outflow. Whether the urine so backed up is or is not infected determines the conditions of infected hydronephrosis or simple

* In the laboratory of Gross Anatomy, Northwestern University Medical School.

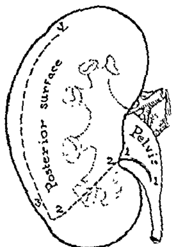


Fig. 543. MOST BLOODLESS INCISION FOR OPENING THE KIDNEY PELVIS AND KIDNEY SUBSTANCE.

1-1 indicates pyelotomy incision; this can be carried obliquely through renal parenchyma as shown in 2-2, thus opening the lower calices; continued incision along 3-3 opens the entire pelvis. (After Kelly, Burnam.)

over the desired area; or occasionally the entire kidney is slit open along Brödel's line in order to expose the calices thoroughly. Hemorrhage is controlled by compressing the vessels in the pedicle, preferably by manual pressure, or by a rubber-shod clamp.

URETER, GREAT VESSELS, AND NERVES

URETER. Toward the level of the inferior end of the kidney, the part of the pelvis lying outside the renal sinus diminishes in caliber to form a musculomucous tube, the ureter, which conveys the urine to the bladder.

In its *abdominal portion* the ureter pursues an almost vertical course downward and medially on the anterior surface of the psoas major muscle, which separates it from the tips of the transverse processes of the lumbar vertebrae. The abdominal segment is divided by the iliac crest into lumbar and iliac portions, each of which measures about 8 cm. On the right side the abdominal ureter lies deep to the peritoneum of the right infracolic compartment. Just before it enters the pelvis the ureter is crossed by the root of the mesentery and the terminal ileum. In its proximal portion it lies behind the descending and transverse parts of the duodenum (Fig. 513). Between the duodenum and the root of the mesentery of the jejuno-ileum, the spermatic, right colic, and ileocolic vessels cross the anterior surface of the ureter and separate it from the peritoneum. Because of these vascular relations, the extraperitoneal lumbo-inguinal approach (p. 413) to the ureter is preferable to the transperitoneal approach. The ureter is attached so closely to the peritoneum that the two are not dissociated when the peritoneum is stripped forward. On the left side the ureter lies deep to the peritoneum covering the left infracolic space. As it enters the pelvis it is crossed by the pelvic mesocolon. The spermatic, left colic, and sigmoid vessels cross its anterior surface (Fig. 516). In resections of the right and left colon the ureters should be located to avoid injury to them (Figs. 513, 525).

The *pelvic portion* of the ureter consists of parietal and intravesical divisions and makes up half the length of the entire tube, about 15 cm. The parietal division, closely related to the peritoneum, crosses the brim of the pelvis in front of, or a little lateral to, the bifurcation of the common iliac artery (Figs. 545, 546, 618 to 620). It descends abruptly between the peritoneum and the hypogastric (internal iliac) artery, which separates it from the posterior wall of the pelvis and the great nerve trunks (Figs. 569, 570). As it approaches the base of the bladder it is related to the superior vesical artery lying above it. Just before entering the bladder in the male it is crossed lateromesially and on its upper aspect by the deferent duct, which intervenes between it and the peritoneum.

In the female the ureter passes to the posterior peritoneal layer of the broad ligament and enters the parametrium, through which it passes forward toward the cervix, inclining downward and medially to reach the wall of the bladder. As the ureter traverses the parametrium it is separated from the supravaginal part of the cervix by a distance of 2 cm. (Fig. 554). At this level it is situated a little more than 1 cm. above the lateral vaginal fornix and is enveloped closely by the veins of the vesical and vaginal plexuses. It is crossed above by the uterine artery, which passes medially to the uterus from the pelvic wall. From the cervix forward the ureter converges toward its fellow and, as it runs forward and medially (Figs. 619, 620, pp. 638, 640) lies first beside the lateral fornix of the vagina and subsequently between the anterior vaginal wall and the base of the bladder, still within the parametrium.

The intravesical course of the ureter measures about 0.5 to 1 cm. and is the most con-

on the affected side; and a scoliosis of the lumbar spine with the concavity toward the lesion. The scoliosis may be the result of splinting action through muscle spasm or of the instinctive effort to increase the loin space. There may be local tenderness, overlying edema, and flexion and adduction of the thigh, since the upper lumbar nerves control those movements.

The abscess, if untreated, may extend posteriorly and point in the lumbar region, usually becoming superficial in the lumbar triangle of Petit (Fig. 393). It may burrow upward through the diaphragm into the pleural cavity and lung, or travel downward and form a large collection in the iliac fossa. Abscesses involving the perirenal tissue secondarily may spread upward in the extraperitoneal tissue after appendicitis or pelvic cellulitis, or pass downward from the pleura by eroding the diaphragm in the interval behind its vertebral and costal attachments. Renal carbuncle is sometimes the source of the perirenal abscess.

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LUMBAR NEPHRECTOMY. The approach for [illegible] nephrectomy is discussed on page 413.

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When a kidney has a large, well defined extrarenal pelvis, it is well to begin all explorations for moderately large stones through the pelvic incision. If necessary, the incision may be extended obliquely through the posterior parenchyma in a caudad direction. If the pelvic incision is too small for removal of the calculus, it cannot be extended in an upward direction because of the posterior branch of the renal artery, which is a large vessel skirting the pelvis. The incision may be enlarged safely in an oblique downward direction over the posterior surface of the kidney. This incision combines pyelotomy and nephrotomy. It often is convenient to remove a part of the stone through the pelvic incision and the remainder through the nephrotomy opening. Incisions in the pelvis heal well if there is not too much infection of the kidney and drainage down the ureter is free. The incisions should be closed by suture in layers when possible.

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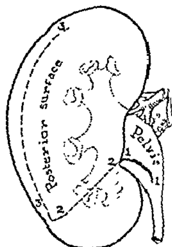


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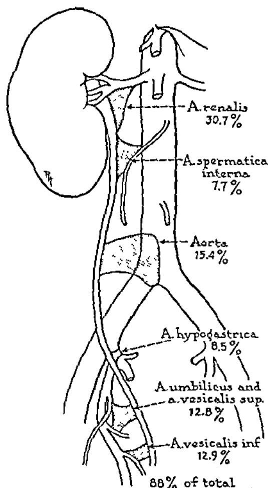


Fig. 545. URETERIC ARTERIES—SCHEMATIC.

Sources of supply indicated, with percentage of vessels from each of the important contributory vessels, in 50 specimens.

The combined percentages cover 88 per cent of the vessels (remaining 12 per cent include vessels derived from the capsular, suprarenal, uterine and urethral arteries). (From McCormack and Anson: Quart. Bull., Northwestern Univ. M. School, 24: 291-4, 1950.)

The area through which the intermediate, or lumbar, segment courses is one in which no primordially retroperitoneal viscera are normally lodged. Therefore the aorta and its continuing stem, with the small number of segmentally arranged lumbar arteries, would, together, be the main source of ureteric branches. These, with some twigs from the spermatic, give a total (fifty) slightly more than half as great as the number (eighty-seven) in the proximal zone, and approximately two fifths as great as the total (123) in the distal zone (Fig. 545).

As it is especially clear in the case of the larger vessels, the ureteric arteries tend to anastomose (Fig. 546, *a*). In some specimens this feature is very evident, the renal and the hypogastric uretérics meeting, as do the descending and ascending branches, respectively, of middle and right colic arteries.

From the clinical standpoint it is important that the ureter is richly supplied by arteries through more than two thirds of its extent. Likewise important is the fact that the heavy retroperitoneal layer housing the ureter contains numerous small arteries which, assumedly, would nourish the duct and keep it viable.

Occasionally the ureter is double through part or all of its course. Rarely the right ureter follows a retrocaval route in its descent from the kidney to the urinary bladder (Fig. 546, *b*). The latter anomaly has occurred but once in a series of 500 cadavers studied.

ABDOMINAL AORTA. The abdominal aorta extends from the aortic hiatus of the diaphragm commonly to the level of the body of the fourth lumbar vertebra, where it divides into three terminal branches, a small median branch, the middle sacral artery, and two lateral branches, the common iliacs. The projection of the termination of the aorta to the anterior abdominal wall corresponds to the midpoint of a line joining the summits of the iliac crests. The aorta gives off visceral and parietal branches.

The VISCERAL BRANCHES comprise the celiac, *superior and inferior mesenteric*, renal, spermatic and ovarian arteries. The relation between points of origins of the visceral branches of the abdominal aorta and the vertebrae is highly variable (Fig. 547). In 100 specimens the celiac artery arose opposite the first lumbar vertebra in 74 per cent of cases; the superior mesenteric in 83 per cent originated opposite

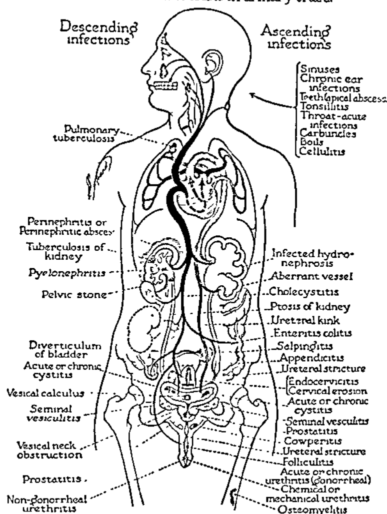


Fig. 544. SOURCES OF URINARY INFECTION.
(From Christopher: Textbook of Surgery.)

tracted part of the duct, being but 3 to 4 mm. in diameter. Calculi naturally lodge at this point.

The *caliber* of the normal ureter is not uniform, but is constricted in certain locations and has long, spindle-shaped dilations between *the constrictions. The uppermost of these con*strictions lies about 5.5 cm. from the kidney pelvis, the next at the brim of the pelvis where the ureter crosses the common iliac artery, and the lowermost just outside the ureteral orifice. The constricted segments are the points of arrest of ureteral calculi. Blockage of the ureter by a calculus often produces an acute hydronephrosis, the symptoms of which may overshadow symptoms directly referable to the seat of impaction of the offending stone. The subjective symptoms of a calculus are explained by the interrelation of the ureteral, vesical and genital nerve supply through the great sympathetic plexuses (Figs. 569, *A*; 570, *A*).

No bodily area of equal size surpasses the renosuprarenal in the number of visceral arteries present. Many of these, in the narrower region of the renal pedicle, are derived from *the main renal or from its hilar branches* and pass superiorly to the adrenal gland. To a striking degree, also, arteries of similar origins are sent lateralward to the ureter, or obliquely downward to an adjacent part of the same duct. Fewer come from the gonadal vessel (spermatic or ovarian) and from the lowermost members of the group destined for the adrenal gland. Their combined presence renders the renal segment of the ureter one of the most profusely vascularized (Fig. 545).

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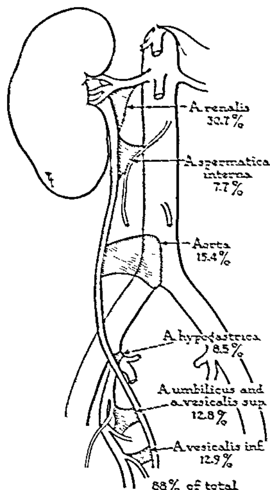


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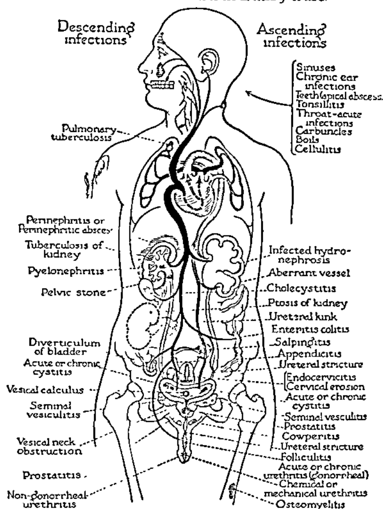


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(From Christopher: Textbook of Surgery.)

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The *caliber* of the normal ureter is not uniform, but is constricted in certain locations and has long, spindle-shaped dilations between the constrictions. The uppermost of these constrictions lies about 5.5 cm. from the kidney pelvis, the next at the brim of the pelvis where the ureter crosses the common iliac artery, and the lowermost just outside the ureteral orifice. The constricted segments are the points of arrest of ureteral calculi. Blockage of the ureter by a calculus often produces an acute hydronephrosis, the symptoms of which may overshadow symptoms directly referable to the seat of impaction of the offending stone. The subjective symptoms of a calculus are explained by the interrelation of the ureteral, vesical and genital nerve supply through the great sympathetic plexuses (Figs. 569, *A*; 570, *A*).

No bodily area of equal size surpasses the renosuprarenal in the number of visceral arteries present. Many of these, in the narrower region of the renal pedicle, are derived from the main renal or from its hilar branches and pass superiorly to the adrenal gland. To a striking degree, also, arteries of similar origins are sent lateralward to the ureter, or obliquely downward to an adjacent part of the same duct. Fewer come from the gonadal vessel (spermatic or ovarian) and from the lowermost members of the group destined for the adrenal gland. Their combined presence renders the renal segment of the ureter one of the most profusely vascularized (Fig. 545).

In the pelvis, as the hypogastric division of the common iliac artery divides into a radiating

set of parietal and visceral stems, there is again offered a potential source of vessels to the several pelvic organs. Most numerous are the vesical arteries, which are sent out like a spray virtually to envelop the urinary bladder. Their rami to the ureter outnumber vessels from any other single source (umbilical, gluteal, obturator, and the like); they supply almost half the total number of vessels to the distal segment of the ureter. Vessels from the several sources sent to the distal (pelvic) segment of the duct make up approximately half of all vessels supplied to the ureter (123 of 260 in fifty specimens studied).

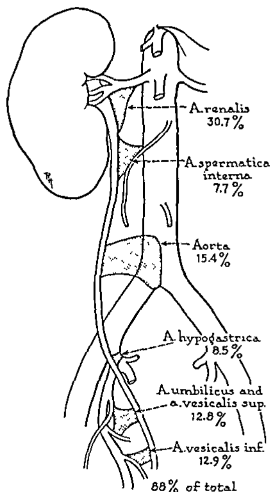


Fig. 545. URETERIC ARTERIES—SCHEMATIC.

Sources of supply indicated, with percentage of vessels from each of the important contributory vessels, in 50 specimens.

The combined percentages cover 88 per cent of the vessels (remaining 12 per cent include vessels derived from the capsular, suprarenal, uterine and urethral arteries). (From McCormack and Anson: Quart. Bull., Northwestern Univ. M. School, 24: 291-4, 1950.)

The area through which the intermediate, or lumbar, segment courses is one in which no primordially retroperitoneal viscera are normally lodged. Therefore the aorta and its continuing stem, with the small number of segmentally arranged lumbar arteries, would, together, be the main source of ureteric branches. These, with some twigs from the spermatic, give a total (fifty) slightly more than half as great as the number (eighty-seven) in the proximal zone, and approximately two fifths as great as the total (123) in the distal zone (Fig. 545).

As it is especially clear in the case of the larger vessels, the ureteric arteries tend to anastomose (Fig. 546, *a*). In some specimens this feature is very evident, the renal and the hypogastric uretcrics meeting, as do the descending and ascending branches, respectively, of middle and right colic arteries.

From the clinical standpoint it is important that the ureter is richly supplied by arteries through more than two thirds of its extent. Likewise important is the fact that the heavy retroperitoneal layer housing the ureter contains numerous small arteries which, assumedly, would nourish the duct and keep it viable.

Occasionally the ureter is double through part or all of its course. Rarely the right ureter follows a retrocaval route in its descent from the kidney to the urinary bladder (Fig. 546, *b*). The latter anomaly has occurred but once in a series of 500 cadavers studied.

Abdominal Aorta. The abdominal aorta extends from the aortic hiatus of the diaphragm commonly to the level of the body of the fourth lumbar vertebra, where it divides into three terminal branches, a small median branch, the middle sacral artery, and two lateral branches, the common iliacs. The projection of the termination of the aorta to the anterior abdominal wall corresponds to the midpoint of a line joining the summits of the iliac crests. The aorta gives off visceral and parietal branches.

The visceral branches comprise the celiac, superior and inferior mesenteric, renal, spermatic and ovarian arteries. The relation between points of origins of the visceral branches of the abdominal aorta and the vertebrae is highly variable (Fig. 547). In 100 specimens the celiac artery arose opposite the first lumbar vertebra in 74 per cent of cases; the superior mesenteric in 83 per cent originated opposite

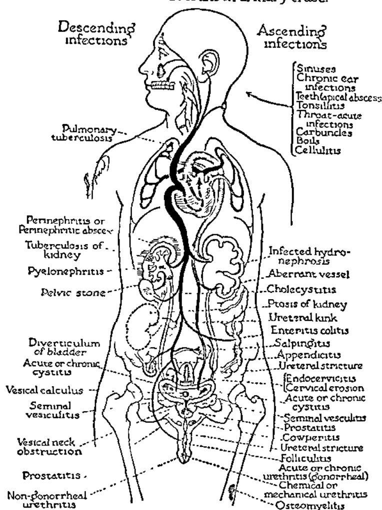


Fig. 544. SOURCES OF URINARY INFECTION.
(From Christopher: Textbook of Surgery.)

tracted part of the duct, being but 3 to 4 mm. in diameter. Calculi naturally lodge at this point.

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No bodily area of equal size surpasses the *renosuprarenal in the number of visceral arteries present.* Many of these, in the narrower region of the renal pedicle, are derived from the main renal or from its hilar branches and pass superiorly to the adrenal gland. To a striking degree, also, arteries of similar origins are sent lateralward to the ureter, or obliquely downward to an adjacent part of the same duct. Fewer come from the gonadal vessel (*spermatic or ovarian) and from the lowermost* members of the group destined for the adrenal gland. Their combined presence renders the renal segment of the ureter one of the most profusely vascularized (Fig. 545).

In the pelvis, as the hypogastric division of the common iliac artery divides into a radiating

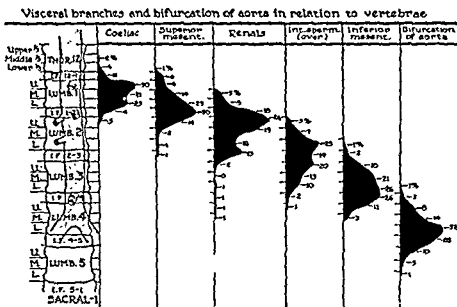


Fig. 547. RELATION OF THE VISCERAL BRANCHES AND POINT OF BIFURCATION OF THE ABDOMINAL AORTA, IN 100 SPECIMENS, TO VERTEBRAL THIRDS AND INTERVERTEBRAL FIBROCARTILAGES.

The data, recorded as percentage occurrence, are converted into a series of curves in which the abscissas are placed vertically, the ordinates horizontally. (From Anson and McVay: Anat. Rec., 67: 7-15, 1936.)

COMMON AND EXTERNAL ILIAC ARTERIES. The two *common iliac arteries* pass obliquely laterally, downward and forward to about the level of the sacroiliac synchondroses, where each bifurcates into an internal iliac (hypogastric) and an external iliac trunk (Fig. 571). Save for their terminals, neither common iliac has collaterals. The terminal ileum on the right and the pelvic colon on the left rest on them. The superior hemorrhoidal branch of the inferior mesenteric artery crosses the left common iliac artery.

Of the two main trunks of the common iliac, the *external iliac artery* alone remains in the abdominal cavity. It runs from the sacroiliac synchondrosis to the lateral side of the lacunar ligament beneath the inguinal ligament, where it becomes the femoral artery. The two branches of the external iliac, the inferior epigastric and the deep circumflex iliac arteries are derivations of the terminal part of the trunk. The external iliac artery is most accessible by the extraperitoneal approach (p. 564).

INFERIOR VENA CAVA. The inferior caval system includes the veins of the body wall below the diaphragm, those of the lower extremities and those from the abdominal and pelvic cavities, save the veins of the portal system.

From its origin in the two *common iliac veins* the inferior vena cava increases in size from below upward with the accession of the various tributaries, and becomes the largest of the body veins. It maintains a close relationship with the abdominal aorta through the major part of its course; its paired tributaries correspond mainly with those of the aorta. Laterally, it lies in contact with the right psoas major muscle, and is related closely to the descending duodenum, the head of the pancreas and the medial margin of the right kidney (Fig. 546).

A thrombosis of the inferior vena cava, or any part thereof, demands an accessory path to the superior cava for the tributary blood. The collateral burden borne by the anastomosing veins of the abdominal wall and the azygos and hemiazygos systems aids materially in shunting the flow from the inferior to the superior cava. In *portal obstruction*, portal blood passes into the caval system along well defined collateral pathways (Fig. 548).

Surgical Considerations

LIGATION OF INFERIOR VENA CAVA. Ligation of the inferior caval vein is now a well established surgical procedure to prevent recurrent pulmonary emboli due to venous thrombosis in the lower extremities or in the pelvis. Routes by which blood may return to the heart, circumventing a ligated part of the inferior vena

the vertebral area from the middle of the first to the upper third of the second lumbar vertebra; and the inferior mesenteric in 73 per cent opposite the vertebral area from the middle of the third lumbar vertebra to the intervertebral fibrocartilage between the third and fourth lumbar vertebrae; the internal spermatic (and ovarian) vessels in 64 per cent of the cases took origin opposite the area from the lower third of the second lumbar to the upper third of the third lumbar vertebra. The bifurcation of the aorta in 84 per cent of the cases occurred in the area between the middle third of the fourth lumbar and the upper third of the fifth lumbar vertebra. Of the four sets of aortic branches just described, the celiac and inferior mesenteric arteries were most concentrated in their areas of origin; then followed in order the superior mesenteric and the internal spermatic (and ovarian) arteries. Most variable in their positions of all the visceral branches were the renal arteries. Although 64 per cent of the renal arteries lay opposite the vertebral column between the intervertebral fibrocartilage of the first and second lumbar vertebrae and the middle third of the latter vertebra, the most superiorly placed examples of these arteries arose opposite the middle of the first lumbar, the most inferior ones opposite the middle of the fourth lumbar vertebra.

The PARIETAL BRANCHES are the paired *inferior phrenic arteries*, arising near the aortic hiatus and supplying the lumbar part of the diaphragm. From them, superior branches to the adrenal glands frequently arise (Fig. 534, *a*). The *lumbar arteries* correspond to the intercostal arteries from the thoracic area and are arranged in four pairs. At the mesial border of the psoas muscle each artery divides into dorsal branches which supply the muscles of the spine, and ventral branches which supply the muscles of the abdominal wall.

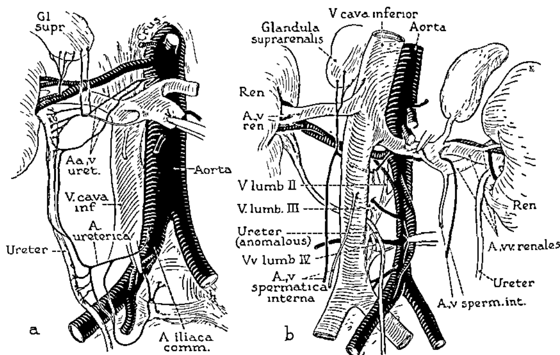


Fig. 546. KIDNEYS, URETERS AND ADRENAL GLANDS, SHOWING FEATURES OF THEIR BLOOD SUPPLY, ESPECIALLY IN RELATION TO THE URETER.

a, Renal, suprarenal and ureteric arteries, showing the manner in which vessels may divide to supply related glands and ducts, and the way in which anastomoses are formed between ureteric arteries which arise at renal and iliac levels. In addition to sending branches to the ureter, the vessels of aortic origin care for part of the vascularization of the adrenal gland; the supply to the latter is here augmented by a branch from a hilar division of the renal artery. (From Pick, Beaton and Anson: Unpublished report.)

b, Renal arteries, renal and caval tributaries, and the relation of the latter to an anomalous (retrocaval) ureter, showing especially the complexity of tributaries to the left renal and of left lumbar tributaries to the inferior vena cava. The internal spermatic arteries are of relatively infrequent type. On the specimen's right the artery sends upward an accessory suprarenal branch; on the left the corresponding vessel at first courses lateralward, then downward after having passed between the 2 limbs of the renal vein. (From Pick and Anson: J. Urol., 43: 672–85, 1940.)

viscera and vessels of the abdominal and pelvic cavities. They are augmented by peripheral branches from the lower thoracic, abdominal and upper pelvic divisions of the gangliated chain, and are related to the central nervous system by communicating rami to the lower *thoracic, upper lumbar, and sacral nerves.* The hypogastric plexus is a connection between the celiac and pelvic plexuses.

LUMBAR SYMPATHETIC GANGLIONECTOMY AND TRUNK RESECTION. These structures can be excised quite well through a lateral extraperitoneal muscle-splitting incision (Fig. 549). The common indication for the operation is to lessen peripheral arterial deficiency due to arteriosclerosis, thromboangiitis obliterans or an obstructing femoral embolus. Occasionally Raynaud's disease, hyperhidrosis and causalgia are so treated. Usually only one side is done, but bilateral resections have been carried out at the same time through two lateral approaches. The earlier midline transperitoneal route is now seldom used.

The second, third and fourth lumbar ganglia with their trunk and rami are dissected free and removed. The clinical results, if the obstructing

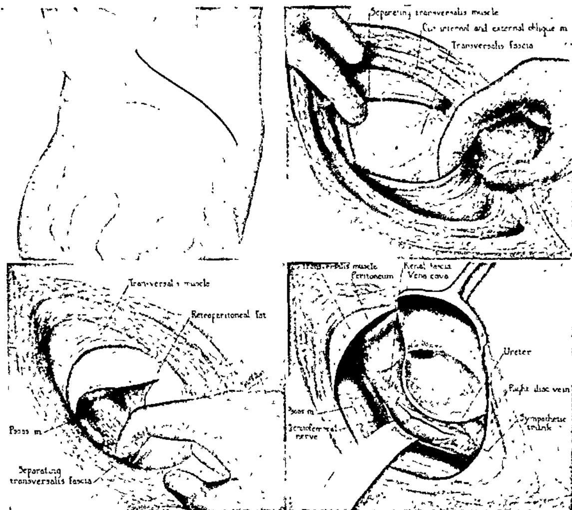


Fig. 549. LATERAL EXTRAPERITONEAL APPROACH FOR LUMBAR SYMPATHETIC GANGLIONECTOMY AND TRUNK RESECTION.

Upper left, Line of incision. *Upper right*, The external oblique muscle split in the direction of its fibers from the costal margin to the rectus fascia, and retracted. The internal oblique muscle is similarly split from the crest of the ilium to the rectus fascia *Lower left*, The oblique muscles retracted, the transversus abdominis muscle fibers separated and retracted. The transversalis fascia is incised anteriorly and well around over the psoas muscle. Preparation is made to dissect the peritoneum widely and retract it medially with the abdominal viscera. *Lower right*, The renal fascia has been severed, the psoas muscle retracted laterally, and the vena cava (on the right) and ureter medially, thus exposing the sympathetic chain for its removal from the diaphragm to the brim of the pelvis. (From Flothow and Swift: Am J. Surg., 21: 345-53, 1933.)

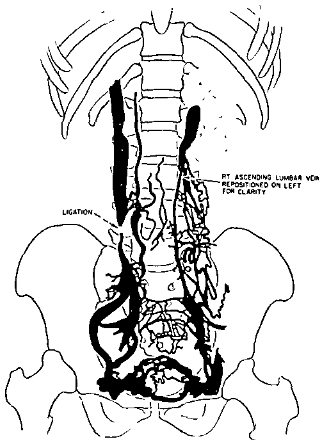


Fig. 548. ROUTES OF VENOUS RETURN FOLLOWING EXPERIMENTAL LIGATION OF THE INFERIOR VENA CAVA.

A composite of the several channels demonstrated roentgenographically. Note that the ascending lumbar veins are especially important elements in the system of collaterals by which blood may return to the heart, circumventing the inferior vena cava. (From Surington and Jonas: Arch. Surg., 65: 605–609, 1952.)

cava, have been demonstrated by intra-abdominal venography (Surington and Jonas). The chief channels are the following: ascending lumbar veins and their communications with the azygos and hemiazygos veins in the thorax; vertebral veins; ovarian veins; ureteral veins; superficial veins of the trunk (Fig. 548). The left (accessory) inferior vena cava may deservedly be added to the channels just enumerated (Fig. 537). In recent examination of sixty-six laboratory specimens, five examples of the left caval vein were found; and from earlier records, on a total of 550 cadavers, it may be said that the accessory vessel was the smaller of the pair except in four instances—in three of which the caval channels were of approximately equal caliber, and in one the vessel on the right side was the larger (Anson).

RETROPERITONEAL LYMPHATICS. The retroperitoneal space is rich in lymphatic structures, which form a chain extending from the inguinal ligament to the diaphragm. The many nodes and vessels are grouped about the great vascular trunks of the region and unite the lymphatic drainage from the extremities, pelvis and abdomen with that of the mediastinum.

The more differentiated groups of lymph nodes are the iliac and lumbo-aortic glands. The *iliac lymph nodes*, grouped about the external and common iliac vessels, receive afferent vessels from nodes in many different areas, including those draining almost the whole of the pelvic contents and also the inguinal and subinguinal nodes draining the lower extremity. The *lumbo-aortic nodes* are remarkable for their large number. They lie in superficial and deep groups about the aorta and inferior vena cava and receive the efferents of the intestines and their mesenteries. The vessels leading from the lumbo-aortic nodes open into the *cisterna chyli*, which is scarcely more than a dilated ampulla of the *thoracic duct* (Fig. 326, p. 338).

ABDOMINAL AND PELVIC DIVISIONS OF THE SYMPATHETIC GANGLIATED CHAIN AND THEIR PLEXUSES. The *abdominal* or *lumbar division* of the gangliated chain consists of ganglia and connecting association cords lying in the retroperitoneal space, anterior to the lumbar vertebrae and mesial to the psoas major muscles (Fig. 550, *A*). The left cord is concealed partially by the aorta, the right by the vena cava. Association cords connect the abdominal with the thoracic and pelvic divisions. Central branches or communicating rami pass in an irregular fashion from the gangliated trunk to the anterior rami of the lumbar nerves (Fig. 551). They run beneath the origins of the psoas major muscle over the vertebral bodies. Occasionally they pierce the fibers of the muscle. Peripheral branches supply the aortic subdivision of the celiac plexus.

The *pelvic* or *sacral division* of the gangliated chain lies on the pelvic surface of the sacrum mesial to the anterior sacral foramina. Irregular central or communicating rami connect the sacral ganglia with the anterior rami of the sacral and coccygeal nerves.

The peripheral branches of the gangliated chain are characterized, as in the neck and thorax, by the formation of, or association with, plexuses in their neighborhood. These plexuses lie on a plane anterior to that of the gangliated cords. The celiac, hypogastric and pelvic plexuses serve to distribute nerves to the

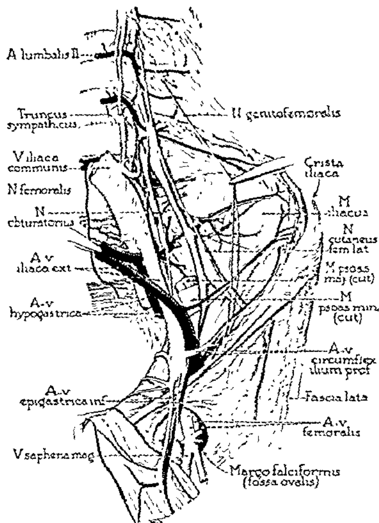


Fig. 551. LUMBAR, PELVIC AND FEMORAL VESSELS AND NERVES; ANTERIOR VIEW.

In the lumbar region the quadratus lumborum muscle has been removed, except at the line of iliac attachment, to expose the anterior leaf of the lumbodorsal fascia and the lumbar vessels and nerves as they rest upon, and pierce, this layer. In this view are seen the named nerves of the lumbar plexus as they descend upon the anterior surface or along the medial border of the iliacus muscle. Also shown are the iliolumbar vessels. The iliac vessels, like the corresponding lumbar muscular rami, are followed to the points at which they pierce the iliacus muscle. The deep circumflex iliac vessels are also traced to their muscular terminations. The inferior epigastric vessels, passing from the external iliacs to the rectus muscle, are turned downward and forward with the muscle. In the thigh the skin and superficial fascia have been removed to expose the fascia lata in the area over the femoral triangle.

tend to become lodged at major bifurcations of peripheral arteries, in one series the site in 335 cases* being subclavian, two; axillary, eighteen; brachial, forty; radial, two; ulnar, one; aorta, thirty-four; common iliac, fifty; external iliac, ten; common femoral, 131; superficial femoral, eleven; popliteal, thirty-three; and posterior tibial, three. *Peripheral embolectomy*, to be of any value, is an emergency procedure, and the successful opening and removal of an obstruction from the aortic or common iliac bifurcation has been frequently done.

Ligation of the common iliac vein is a procedure occasionally carried out in cases of acute or chronic thrombophlebitis or phlebothrombosis to prevent pulmonary embolism. In such circumstances the vessels are often friable, and, once they are torn, hemorrhage is difficult to control. The excellent collateral circulation following ligation of the common iliac vein makes it a preferable procedure to ligation of the common femoral vein (Fig. 553).

* Christopher: Textbook of Surgery. 5th ed. Philadelphia, W. B. Saunders Company, 1949, p. 661.

disease is not too extensive, are an increase in blood supply to the leg and foot of the operated side through vasodilatation of the vessels, particularly from about the level of the knees down. There is also absence of sweating in the same area. Bilateral ganglionectomy inhibits ejaculation during sexual orgasm.

Resection of the Presacral (Superior Hypogastric) Plexus. This operation has restored normal bladder function in certain cases of chronic urinary retention from cord lesions, and has lessened the symptoms of dysmenorrhea and pelvic pain.

The explanation of these results lies in the double sympathetic innervation of the pelvic contents. The bladder obtains its motor (emptying) impulses through the sacral gangliated chain, and gets its inhibitory fibers from the thoracolumbar outflow, which passes through and contributes to the presacral plexus. Removal of the presacral plexus (Fig. 550) removes the brake mechanism to these structures and allows the motor fibers from the sacral outflow to function more efficiently. Excision of these nerve fibers interrupts the pathway of the sensory (afferent) sympathetic fibers from the bladder and pelvic genitals and sometimes alleviates the pain of dysmenorrhea. Fibers which contribute to the presacral (hypogastric) plexus reach it from the preaortic collateral ganglia. The plexus occupies a varying extent between the two common iliac arteries. Occasionally the nerve elements are gathered into a single nerve, the presacral nerve, and not into a plexus. The nerve or plexus is easy of access in front of the fifth lumbar vertebra, and lies in the median line immediately under the peritoneum. Posteriorly, it is separated from the great vessels by loose connective tissue. Lower down on the sacrum, it becomes more intimately related to the underlying bone. The attachment of the mesentery of the small bowel is cephalad to the presacral plexus, and the root of the mesosigmoid lies to its left. It must be remembered, however, that variations in mesosigmoidal attachment are numerous, often striking (Figs. 572, 573).

Surgical Approach to the Aortic Bifurcation, Lower Inferior Vena Cava and Iliac Vessels. Operative procedures on these vessels are now common, and the vessels can be approached intraperitoneally or extraperitoneally (Fig. 552). Emboli to the peripheral arteries arise mainly from the left side of the heart, and less frequently in the aorta. They

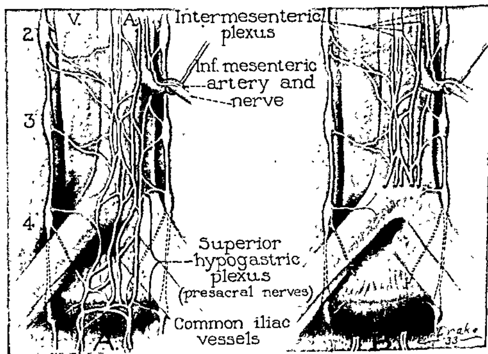


Fig. 550. Resection of presacral nerve.

A, Presacral nerves and their connections; *B*, presacral nerves (superior hypogastric plexus) removed. (Adson and Masson, Mayo Clinic.)

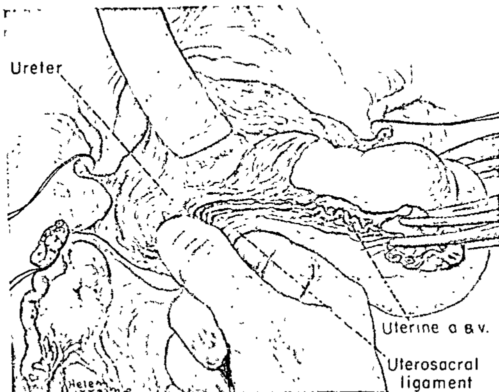


Fig. 554. AVOIDANCE OF INJURY TO THE URETER DURING HYSTERECTOMY.

The difficult and dangerous part of the operation begins with the clamping of the uterine arteries. With the fingers in the position shown the ureter may be felt near the outer aspect of the uterosacral ligament. The uterine arteries are then divided well medial to this point. (From Burch and Lavely: Tr. Am. Surg. A., 70: 383–95, 1952.)

Ligation of the inferior vena cava has been done for bilateral thrombosis of the main venous channels of both legs.

INJURY TO THE URETERS. Benson and Hinman,* recently emphasized the four danger zones where injury to the ureter may occur. The first, but least dangerous, is the point where the ureter crosses the iliac vessels (Figs. 545, 546, 618 to 620). The second is the ovarian fossa where the ureter comes in close proximity to the adnexa, so long as the ovary and tube remain in normal position (Fig. 618). The third, and most serious point where dam-

* Am. J. Obst. & Gynec., 70: 467–85, 1955.

Fig. 552. EXTRAPERITONEAL APPROACH TO THE BIFURCATION OF THE AORTA AND THE LEFT COMMON AND EXTERNAL ILIAC VEINS.

A, The incision begins in the flank and is carried down parallel to the inguinal ligament. The external oblique muscle is divided in the direction of its muscle and aponeurotic fibers; the internal oblique, transversus abdominis muscles and transversalis fascia are incised in the direction of the skin incision. The peritoneum and enclosed abdominal contents are then retracted medially to clear the vessels. *B*, The common iliac vein lies mesial to and deeper than the artery. Sweeping the peritoneum further to the midline allows exposure of the aortic bifurcation

The approach to the right common iliac vein is easier than the left, because the right vein lies just lateral to the common iliac artery. A little more retraction upward and mesially exposes the vena cava.

This incision is also suitable for exposure of about the lower half of the ureter. (From Homans: Surg., Gynec. & Obst., 79: 70–82, 1944.)

Fig. 553. COMPARISON OF COLLATERAL CHANNELS OF VENOUS RETURN AFTER LIGATION OF COMMON FEMORAL VEIN AND COMMON ILIAC VEIN.

A, Relatively few collateral venous channels after ligation of common femoral vein. *B*, Abundant collaterals around common iliac vein ligation. In women an additional field is offered by the uterine and ovarian veins. Substantiating these anatomic considerations, clinical experience indicates that cyanosis and edema sometimes follow common femoral vein ligation when the superficial and deep femoral systems are thrombosed, whereas such sequelae are rare after common iliac vein interruption. (From Homans: Surg., Gynec. & Obst., 79: 70–82, 1944.)

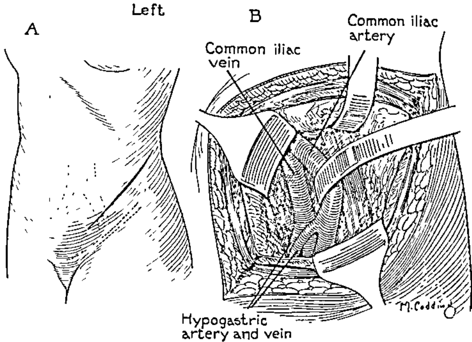


Fig. 552

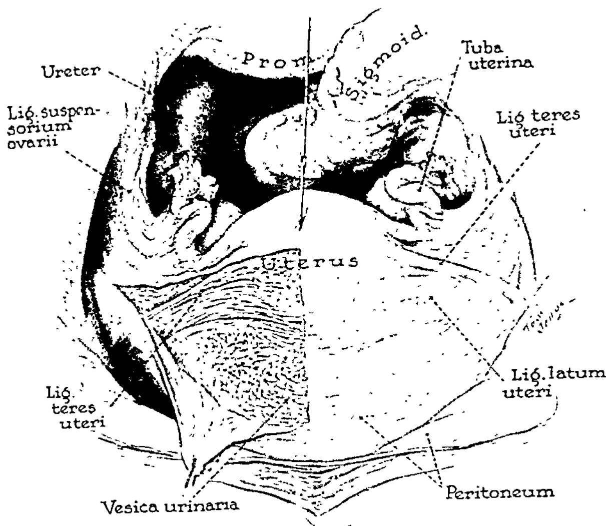
Gluteal
Ligature of common femoral
Hypogastric
Obturator
Median circumflex femoral
Superf femoral
Deep femoral
Long saphenous
A

Deep epigastric
Superf epigastric
Deep circumflex iliac
Ligature of common iliac
Gluteal
Iliolumbar
Inf mesenteric
Hypogastric
Obturator
Hemorrhoidal plexus
Median circumflex femoral
Superf femoral
Deep femoral
B

Fig. 553.

PART V

The Pelvis



FEMALE PELVIS; SEROUS AND SUBSEROUS LAYERS

age is likely, is where the ureter is crossed by the uterine artery. This position is importantly involved in doing a hysterectomy, and the ureter can be felt at this point in the operation (Fig. 554). A fourth danger point is at the base of the bladder, where incisional damage or kinking of the ureter can occur (Fig. 597).

Benson and Hinman list the points in avoidance of ureteral damage as follows:

1. Do not operate without adequate preliminary studies of the urinary tract and knowledge of the anatomy and pathology involved.

2. Catheterize the ureters preoperatively, and recognize the ureter initially in all difficult cases.

3. Identify all structures before clamping, incision and ligation.

4. Avoid undue traction and needless denudation of the ureter and base of the bladder. Uterine arteries (Fig. 545) may be seriously damaged and a slough of the ureter occur.

5. Use deft technique with fine absorbable suture material in or about the urinary tract.

6. Be careful and resourceful, and apply pressure, not mass ligature, for hemorrhage, then secure the bleeding point.

7. Splint the ureter, drain the bladder, and drain the wound cavity (extraperitoneally) in suspected urinary tract injury.

8. Order ample and well chosen chemotherapy in complicated cases.

In pelvic surgery the grave fault lies not so much in the injury of the ureter (or bladder), but in failure to recognize the damage. The most important consideration is the provision for adequate drainage of the kidney, whether by properly executed re-anastomosis or by diversion of the urinary stream. The dangers of unrecognized ureteral damage lie in extravasation of infected urine. Such extravasation will lead to irreversible pathological changes.

CHAPTER 16

Bony and Ligamentous Pelvis

The pelvis is the skeletal base of the trunk and transmits the weight of the superjacent torso to the lower limbs. The bones which enter into its formation, the sacrum and coccyx behind and the innominate bones laterally and anteriorly, articulate with each other to form a complete ring and are maintained in position by large and powerful ligaments. Topographically, the pelvis consists of a bony and ligamentous framework, and includes the soft parts clothing its inner and outer aspects and the pelvic contents. It is closed inferiorly by layers of muscle and fascia which constitute the pelvic diaphragm.

From the surgical viewpoint certain parts of the pelvic composite are discussed best in other regions. The pelvic diaphragm serves as the floor of the perineum. The structures lying on the iliac floor of the false pelvis are considered in that region. The soft parts related to the outer wall of the pelvic framework are discussed in the sections on the gluteal region, the adductor region of the hip, and the anterior region of the thigh.

The bony and ligamentous pelvis is divided into the bony pelvis as a whole and the sacroiliac and sacrococcygeal regions.

Pelvis as a Whole

DEFINITION AND BOUNDARIES. The pelvis, in the broadest meaning of the term, is the anatomical area bounded behind by the sacrum and the coccyx, and at the sides and in front by the innominate bones (Fig. 555; compare Figs. 623 and 624, p. 644). The whole region is divided into an upper part, the greater pelvis (O.T., false pelvis) and a lower part, the lesser pelvis (true pelvis) by the margin of the *linea terminalis*, which, curving downward and forward, consists on either side of the upper border of the first sacral vertebra, the arcuate line of the ilium, and the pectineal line of the pubis.

The greater pelvis is the expanded portion of the entire cavity above the linea terminalis (Figs. 623, 624). Posteriorly it is deeply notched on each side between the ilium and the lumbar vertebrae; laterally it is bounded by the iliac fossae on the inner aspects of the alae; anteriorly, where the bony wall is deficient between the ilia, the boundary is furnished by the abdominal parietes.

The lesser pelvis is the contracted portion below and behind the linea terminalis. Since it is the part of the pelvis concerned in childbirth, it will be the subject of our anatomical account. The lesser pelvis may be divided into an inlet, bounded by the superior circumference, an outlet, limited by the inferior circumference, and a cavity. The superior circumference forms the brim of the pelvis and encloses the oval space termed the superior aperture, which corresponds to the plane of the superior strait. The circumference of the inlet is formed by those eminences, mentioned above, which divide the whole pelvis into two portions, namely, the anterior margin of the base of the sacrum behind, the arcuate and pectineal lines at the sides, and, in front, the continuation of the pectineal line of each half into the tubercle and the crest of the pubis. The inferior circumference forms the outlet of the pelvis, and is of irregular outline. It includes the space called the inferior aperture and lies in the plane of the inferior strait. It is bounded behind by the tip of the coccyx, at the sides by the ischial tuberosities, and in front by the pubic arch, which is formed by the inferior rami of the ischium and the pubis as these converge from either side toward the pubic symphysis. Between the ischial tuberosity anteriorly and the coccyx and sacrum

that caused by deviation of the vertebral column or infection in the innominate bones, sacrum or pelvic joints, tends to produce deformity of the pelvis. Recognition of deformed pelves is of the greatest importance in obstetrics.

The innominate bone presents two groups of ossifying centers, acetabular and marginal. Of the *acetabular centers*, that for the development of the ilium appears during the second fetal month and grows rapidly toward the upper part of the bone. A center for the ischium appears below the acetabulum at the fourth month, but the pubic center is later in development (fifth to sixth month). The union of these ossifying centers, as a rule, occurs near puberty. The pubic and ischial rami unite about the tenth year.

The *marginal centers* include those for the crest of the ilium, anterior superior spine, tuberosity of the ischium, angle of the pubis, and the spine of the ischium. The site of predilection for osteitis is the bone about actively growing centers. Osteitis of the regions about the acetabulum occurs early during the active growth of the acetabular centers, but marginal osteitis is a postpuberty disease occurring between the fifteenth and thirtieth years.

Function. The bony and ligamentous pelvic mechanism is designed to serve three functions: to protect the pelvic viscera, support the vertebral column, and facilitate locomotion.

The pelvic girdle *protects the viscera* contained within its canal from all ordinary trauma, so that only through the abdominal wall above or the perineum below are they likely to be injured, although they may be damaged in penetrating wounds through the obturator foramina and the sciatic notches. If the resistance of the bony pelvis is overcome, resulting in fracture, the bony fragments may become damaging factors and produce bladder laceration or perforation (p. 612) or rupture of the urethra (p. 515). For this reason all fractured pelves require scrupulous clinical observation.

In *supporting the weight* transmitted through the spine, the sacrum is forced downward, so that the sacral promontory faces forward and downward in the pelvis. In sitting, the weight is transmitted to the ischial tuberosities; in standing, it is transmitted down the thighs. The acetabulum, in order to act efficiently as a supporting mechanism, must be of sufficient strength to resist the heavy pressure from the head of the femur in the erect posture. Its only

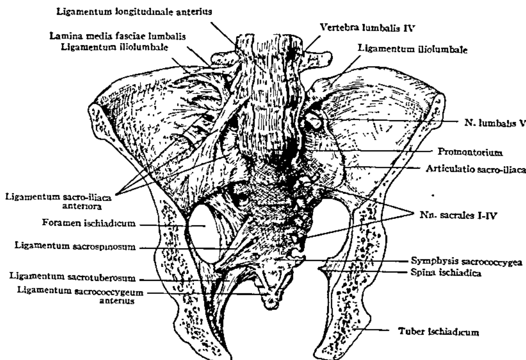


Fig. 556. POSTERIOR ARCH AND ANTERIOR LIGAMENTOUS SUPPORT OF THE PELVIS.

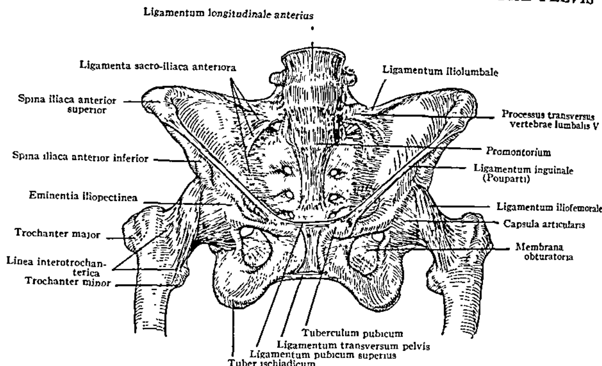


Fig. 555. ANTERIOR VIEW OF THE PELVIS.

posteriorly the bony wall of the pelvis is incomplete, and the deficiency assumes the form of a deep notch to either side of the middle line. This wide interval is bridged across and partially filled by the sacrospinous ligament (small or anterior sacrosciatic ligament) and the sacrotuberous ligament (great or posterior sacrosciatic ligament), which convert it into two foramina above and below the spine of the ischium, the greater and the lesser sciatic foramen, respectively. The inferior margin of the sacrotuberous ligament thus assists in determining the shape of the pelvic outlet.

The cylindrical canal which ends above at the pelvic brim or inlet and below at the outlet is termed the cavity of the pelvis. This osseoligamentous space is clothed on its internal surface by a series of muscles and their investing fasciae (pp. 584, 587) which considerably alter its form; on each lateral half these muscles are the piriformis and coccygeus posteriorly, the obturator internus laterally, and the levator ani inferiorly. The levatores ani, together with the coccygei, constitute a musculoaponeurotic partition called the pelvic diaphragm, which separates the space of the pelvis above from that of the perineum below. The pelvis contains the bladder in the anterior part of the space, the rectum in the posterior, and, between these, the generative organs, comprising the uterus, vagina and uterine appendages. The perineum is traversed by the terminal portions of these three organ systems—the urinary, digestive and genital—and their orifices open below upon its surface (Fig. 616).

SURFACE ANATOMY. The pubic symphysis and the pubic tubercle, about 2.5 cm. lateral to it, can usually be palpated. The anterior superior spine is made out readily, but the anterior inferior iliac spine is too deep to be felt. The outer lip of the iliac crest can be followed to the posterior superior iliac spine, which lies on a level with the middle of the sacroiliac joint. In the erect position a line drawn from the posterior superior iliac spine to the anterior superior spine inclines forward and downward, making an angle of about 15 degrees with the horizontal. The angle is increased in the heavy anatomical type and decreased in the slender type. The gluteal musculature masks the lateral flare of the ilium. The dorsal surface of the sacrum and its spinous processes, the ischial tuberosity, and the inferior ramus of the pubis can be palpated. By vaginal and rectal examination the framework of the pelvic canal can be felt.

DEVELOPMENT AND STRUCTURE. At birth the pelvis is small and poorly developed. It is cone-shaped, and the sacrum is almost vertical. The characteristics of the adult pelvis are determined gradually during the process of growth. Abnormal weight distribution, such as

that caused by deviation of the vertebral column or infection in the innominate bones, sacrum or pelvic joints, tends to produce deformity of the pelvis. Recognition of deformed pelves is of the greatest importance in obstetrics.

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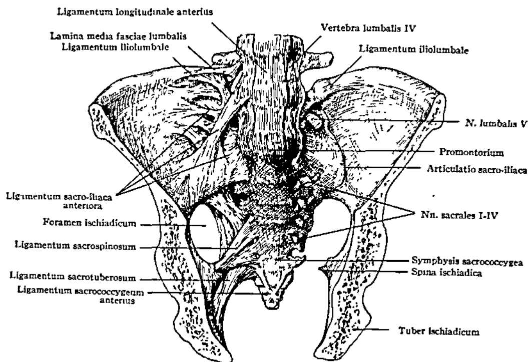


Fig. 556. POSTERIOR ARCH AND ANTERIOR LIGAMENTOUS SUPPORT OF THE PELVIS.

weak feature is the thinness of its floor, the result of the union of the three acetabular centers of ossification.

By ignoring the flares of the ilia, the bony pelvic ring or girdle may be regarded as a *stabilizing mechanism adapted to locomotion.* It is comprised of a main posterior arch and a complementary anterior or counterarch for the support and distribution of the body weight in standing and the additional thrust in locomotion. The posterior arch consists of the three upper sacral vertebrae contributing to the sacroiliac joint, the sacroiliac articulations, and the exceedingly strong pillars of the hip bone running from the sacroiliac joint into the acetabular cavities. The anterior or counterarch consists of the bony masses which run forward from the bodies of the ilium and ischium to form the pubis at the summit of the arch. The line of union of the two arches lies in a frontal plane through the acetabular cavities.

The segments of the arches are tied together by three joints, an interpubic and two sacroiliac (Figs. 555, 556). The slight elasticity in the pelvic girdle afforded by the presence of these joints materially lessens shock. Their comparative freedom from movement affords stability indispensable in efficient locomotion. Laxity in these joints causes pain and interferes materially with locomotion.

Sexual Differences in the Pelvis. The female pelvis differs in form and dimensions from that of the male. The pelvic inlet in the female is oval; that in the male is heart-shaped. In general, the female pelvis is more regular in outline. In the male pelvis the sacral promontory is more prominent, and the sacrum is longer and more curved. Although the extreme width of the pelvis does not differ materially in the sexes, the flares of the ilia are flatter, the pelvic cavity is broader and shallower, the acetabula and the ischial tuberosities are set farther apart, the bony walls of the pelvic canal are more vertical, and the subpubic angle is broader in the female than in the male.

Obstetrical Measurements. The diameters of the superior strait (pelvic inlet), middle strait (pelvic canal) and inferior strait (pelvic outlet) are of practical importance in obstetrics (Fig. 557).

The transverse diameter of the *superior strait* is the greatest distance between the linea arcuata on either side, and measures from 13 to 14 cm. The anteroposterior diameter measures 11 cm. from the sacral promontory to the superior margin of the symphysis. The oblique diameter, measured from the sacroiliac joint to the opposite pectineal eminence, is about 12.5 cm. If the superior strait is contracted, the fetal head cannot engage in the pelvis.

The greatest diameter of the *middle strait* of the pelvis, the anteroposterior, is 12 cm., measured from the third sacral vertebra to the middle of the pubic symphysis. The fetal head, after traversing the inlet by way of the greatest

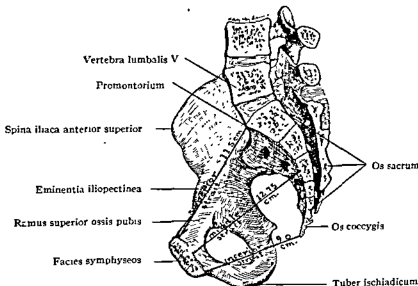


Fig. 557. LATERAL VIEW OF THE FEMALE PELVIS, INDICATING THE PLANES AND MEASUREMENTS OF THE ANTEROPOSTERIOR DIAMETERS.

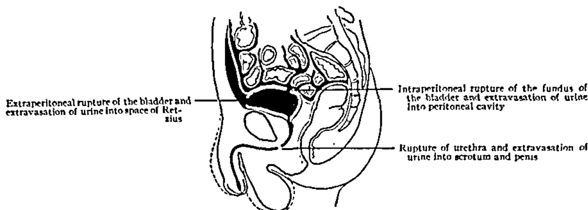


Fig. 558. MOST FREQUENT COMPLICATIONS OF FRACTURE OF THE PELVIS.

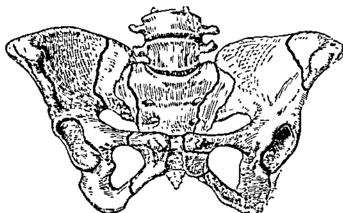


Fig. 559. WEAK AREAS OF THE PELVIS WHICH INDICATE THE LINES OF THE COMMONER FRACTURES.

available diameter, accommodates itself by rotation to the greatest available diameter of the middle strait. The diameters of the superior and middle straits are bony and incapable of distention.

The anteroposterior diameter of the *inferior strait*, which extends from the tip of the coccyx to the inferior margin of the symphysis, is 9 cm., but may be increased 2 or 3 cm. because of the movability of the coccyx. The transverse diameter of the outlet, between the two ischial tuberosities, is from 10 to 12 cm.

FRACTURES OF THE PELVIS. The bony pelvis has great power of resistance to trauma, and gives way and fractures in its weak areas only when the limits of its elasticity are reached (Figs. 558, 559). Its strongest portions are the lateral parts of the innominate bones; its weakest, the sacroiliac region, the alae of the ilia, and the pubo-obturator areas. Pubo-obturator fractures are frequent and, because of their proximity to the bladder, exceedingly dangerous.

When the pelvis is compressed anteroposteriorly by *indirect violence*, as in a squeezing accident, the brunt of the acting force is borne by the weak anterior counterarch, with resulting fracture of the pubic rami. The strong ligaments uniting the pubes tend to maintain the integrity of the symphysis. If the force continues to act, the strong posterior arch is spread forcibly, throwing a strain upon the sacroiliac joints. The joints are bound so firmly by ligaments that they seldom tear; fracture of the adjacent bones is much more frequent.

When the squeezing force is applied transversely, the acetabula are pressed forcibly toward one another. Since the anterior arch is weaker than the posterior, the former often gives way, and continuing violence forces the two ilia together. Continued strain falls upon the sacroiliac joints, and their posterior ligaments may tear away a portion of adjacent bone.

In falls upon the feet or upon the ischial tuberosities, the main arch may escape injury

because of its strength, but the anterior arch sometimes is fractured, or the acetabulum may be injured and the femur be driven through the thinnest part of the acetabular fossa into the pelvis (p. 929). In young persons the acetabulum may be broken into its three anatomic segments, or its rim may be torn away. When a double vertical fracture occurs through both ischiopubic rami anteriorly and the ilium near the sacroiliac joint posteriorly, there is a large pelvic fragment, more or less movable with the femur, which sometimes presents the picture of fracture of the neck of the femur.

Any part of the pelvis, even the sacrum, may be broken by well localized *direct trauma.* The crest or any of the spines of the ilium may be knocked off or torn away, or the epiphyses of the iliac crest and spines be separated. In spite of the tremendous pull on the ischial tuberosities by the hamstring muscles, injury of the tuberosities is comparatively rare.

Much of the gravity of pelvic fractures depends upon the occurrence of *visceral complications.* Large pelvic vessels frequently have been torn in fractures running to the brim of the pelvis. Rupture of the bladder (p. 612) or urethra (p. 515) may result from the penetration of a splinter or fragment of bone.

Sacroiliac Region

DEFINITION AND BOUNDARIES. The sacroiliac joints embrace the expanded portion, or three upper segments, of the sacrum and the articular surfaces of the ilia (Figs. 555, 556, 560). The two joints are important elastic buffers between the spinal column and the lower extremities, and contribute to the posterior arch of the pelvic girdle (p. 571).

SURFACE ANATOMY. Mesial to the easily palpable, blunt, posterior superior iliac spine is a depression corresponding to the sacroiliac joint line. The underlying, tense soft parts offer great resistance to deep palpation in examination for tenderness following strain. On the sacrum near the joint line a row of dorsal projections, corresponding to the rudimentary, fused transverse processes of the sacral vertebrae, may be palpated. Mesial to the transverse processes are the posterior sacral foramina (Fig. 564).

SACROILIAC JOINT. The articulating surface of the sacrum is directed posteriorly and laterally, while that of the ilium is directed forward and mesially. The plane of the joint looking from the pelvis is directed posteriorly and mesially, and the joint space is an unevenly curved slit. The articular surfaces, in the main,

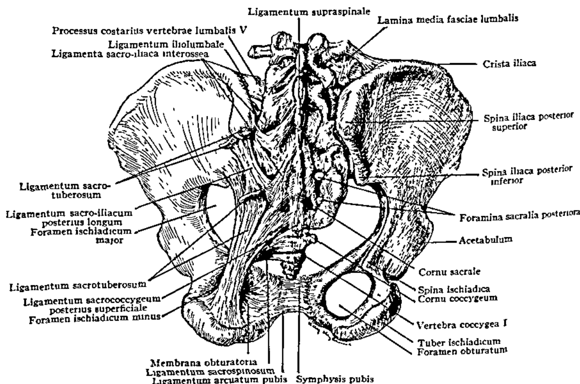


Fig. 560. POSTERIOR LIGAMENTOUS SUPPORT OF THE PELVIS.

are smooth, but they have several irregular projections and depressions which help to lock and stabilize the joint.

Posterior to the articulating areas, the bony surfaces of the sacrum and ilium are rough, for attachment of the strong reinforcing *ligaments*. The short, posterior interosseous ligament crosses the longitudinal depression behind the joint. The long and short posterior sacroiliac ligaments constitute a strong, expansive mass of fibrous bands, extending obliquely outward to the ilium from the lateral sacral crest, and also reinforce the posterior joint line. The sacrotuberous and sacrospinous ligaments, which arise over the whole area of the posterior sacroiliac ligaments and are anchored into the ischial tuberosity and spine, further stabilize the joint. The anterior sacroiliac ligament consists of broad, thin, fibrous plates extending from the sacrum to the medial surface of the ilium. The iliolumbar ligament is a strong, expansive, fibrous band extending from the posterior part of each iliac crest and the adjacent sacrum to the transverse process of the fifth lumbar vertebra. As the transverse processes of the fifth lumbar vertebra lie at a lower level than the crests of the ilia, the iliolumbar ligaments act as a hammock for this vertebra. In this way they oppose the shearing force of the superimposed body weight. The short thin capsule which connects the margins of the articular surfaces of the sacroiliac joint is reinforced anteriorly by the iliolumbar and anterior sacroiliac ligaments (Fig. 560).

Weight-bearing in unfavorable conditions of posture and muscle balance may strain one or the other joint and weaken it, so that recurrence of injury is common, even to the point of producing a chronically relaxed or strained joint. A strained joint requires fixation or stabilization sufficient to restrain the movements of the lower segments of the spine, particularly those at the lumbosacral connection. A subluxated joint may require manipulative reduction in addition to fixation and stabilization.

The ordinary tests to demonstrate a lesion in the sacroiliac joint are straight leg-raising (Kernig's sign), hyperextension of the extremity on the trunk, and prone knee flexion (Fig. 561). *Straight leg-raising* takes advantage of the insertion of the sacrotuberous ligament on the ischium, where the great hamstring muscles from the hip to the leg originate. When the hamstrings are stretched in this maneuver, they pull on the ischium and strain the sacroiliac joint, because they tend to rotate the ilium posteriorly. *Forced hyperextension* of the extremity puts strain on the anterior ligaments of the hip joint and on the corresponding sacroiliac joint, tending to rotate the ilium forward. *Knee flexion* with the body in the prone position also rotates the ilium forward by tensing the quadriceps muscle and making traction upon the anterior iliac spines (Pitkin).

In lesions of the sacroiliac joint there is radiation of pain to any or all of the following locations: buttocks, posterior and lateral portions of the thigh, posterior and lateral leg, lateral side of the foot, and occasionally the groin. A characteristic list of the trunk to one side or the other for relief from pain, and induced spasm in the spinal muscles cause scoliosis and are common manifestations of sacroiliac strain.

Chronic osteoarthritis with spur formation is potential of disability upon slight injury. In old age the sacroiliac articulation may undergo bony changes resulting in an immovable joint (synarthrosis).

Hyperextension of the hip with fixation of the pelvis and lumbar spine is a valuable diagnostic procedure in the differentiation between sacroiliac and lumbosacral lesions, and between right- and left-sided lesions. The patient, lying supine, flexes the knee and hip on the same side acutely, the thigh being crowded against the abdomen with the aid of both the patient's hands clasped about the flexed knee (Fig. 561). This brings the lumbar spine firmly in contact with the table, and fixes both the pelvis and the lumbar spine. The patient then is brought well to the side of the table, and the examiner slowly hyperextends the opposite thigh with gradually increasing force by pressure of his hand on the top of the knee. With the opposite hand the examiner assists the patient in fixing the lumbar spine by pressure over the patient's clasped hands. The hyperextension of the hip exerts a rotating force on the corresponding half of the pelvis in the sagittal plane through the transverse axis of the sacroiliac joint. The pull is made on the ilium through the Y ligament and the muscles attached to the anterior superior and anterior inferior spines. As a result of the impaired ligamentous support on the diseased side, this rotating force causes abnormal mobility accompanied by pain, either local or referred on the side of the

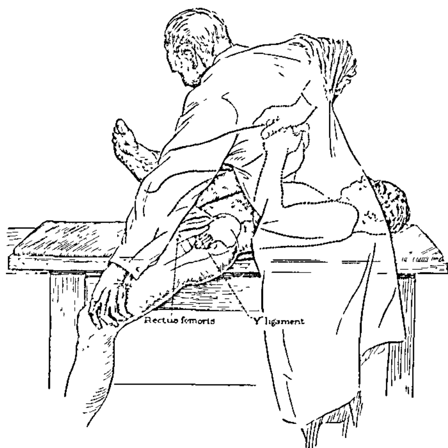


Fig. 561. TEST FOR DIFFERENTIATION BETWEEN LUMBOSACRAL AND SACROILIAC LESIONS.
Demonstration of forcible hyperextension of the left hip, with the pelvis and lumbar spine fixed by means of extreme flexion of the right hip. Pain generally is present in sacroiliac lesions and absent in lumbosacral lesions (Gaenslen)

lesion. Confirmation of the observations thus made by carrying out this test on the opposite side generally is possible (Gaenslen).

Inordinate and disadvantageous stress and strain may occur also at the union between the fifth lumbar vertebra and the sacrum. The fifth lumbar vertebra shows many irregularities and developmental anomalies which play a role in low-back injuries. Remedy of strain in the lumbosacral joint, as in the sacroiliac joint, requires restraint of movements by fixation.

SACROILIAC TUBERCULOSIS. The masses of cancellous bone contiguous to the sacroiliac articulation are sites for tuberculous infection. The pus may course deep to the *iliolumbar* ligament and reach the psoas muscle, which it follows into the thigh (Fig. 530). The products of the infection may escape from the pelvis through the greater sciatic foramen and elevate the gluteus maximus muscle (p. 540), follow the piriformis muscle, and point at the posterior thigh near the great trochanter, or follow the sheath of the sciatic nerve. Infectious products may run along the curve of the sacrum and rupture into the rectum or invade the ischiorectal fossae (p. 697).

Surgical Considerations

APPROACHES TO THE SACROILIAC JOINT. The sacroiliac joint is exposed for the curettement of diseased tissue in tuberculosis, for the removal of debris and drainage in osteomyelitis, and for joint fusion in post-traumatic disabling conditions which have resisted conservative methods of treatment.

In the *Smith-Petersen approach* an incision is made along the posterior two thirds of the *iliac* crest, curving around *the posterior superior* spine and then running parallel to the fibers of the gluteal muscles for a distance of 8 to 10 cm. The soft tissues are reflected subperiosteally until the posterior portion of the lateral surface of the ilium is exposed. The center of the surface overlying the joint is 2.5 cm. superior to the upper border of the sciatic notch and 2.5 cm. anterior to the posterior superior spine. With this point as a *center*, a

block or window of ilium, 2.5 by 4 cm., is removed, the longer side being parallel to the upper margin of the notch. This exposure is adequate for curettement and drainage of the joint. In an arthrodesis the cartilage is removed from the sacral joint surface, exposing cancellous bone, and from the joint surface of the block of ilium. The bone block is replaced and countersunk so that its cancellous portion comes into contact with the cancellous bone of the sacrum.

In *Picque's approach* an incision is made along the posterior surface of the iliac crest and continued downward to the border of the sacrum at a point midway between the posterior superior and inferior spines of the ilium. The soft parts are reflected downward subperiosteally from the crest of the ilium. The bone of the crest is divided from the forward confines of the incision to the posterior inferior spine, exposing the sacroiliac joint.

Campbell has devised an entirely *extra-articular fusion operation* to avoid contamination of the joint. A subperiosteal incision over the posterior half of the iliac crest exposes the posterior surface of the dorsum of the ilium, and a downward vertical continuation of the incision exposes the lateral half of the posterior surface of the sacrum. A portion of the crest is removed, and the mesial surface of the overhanging part of the crest and the adjacent posterior surface of the ilium are denuded. This makes a raw gutter parallel to the sacroiliac joint, formed by the posterior surface of the sacrum and the medial surface of the ilium behind the sacroiliac joint. Into this space the graft from the crest is placed, as well as grafts or "shavings" from the dorsum of the ilium, until the interval is filled.

Occasionally the lumbosacral joint also must be fused. A graft from the crest of the ilium or one from the tibia can be used. It is inserted into the spinous processes of the lower lumbar vertebrae and sacrum.

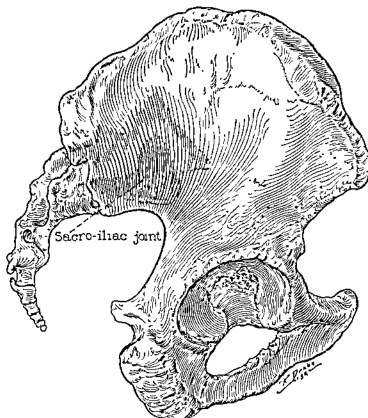


Fig. 562. PROJECTED SURFACE OF THE RIGHT SACROILIAC JOINT.

The level of the inferior margin of the sacroiliac joint runs parallel to the superior margin of the sacrosciatic notch. (From Ghormley: J.A.M.A., 101: 1773-7, 1933.)

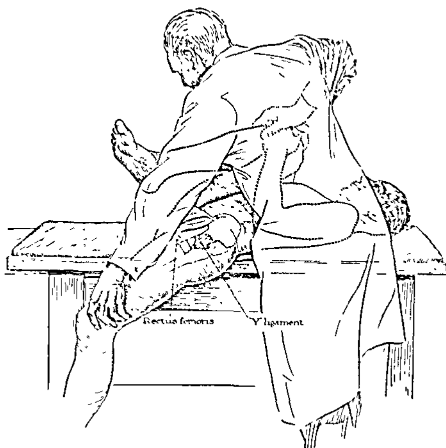


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processes and the lateral sacral crests. At the base of the sacrum, overlying the lumbosacral articulation, the musculotendinous mass is thick and strong, affording much strength to the stabilizing mechanism of the lower back.

SKELETAL STRUCTURE. The *sacrum* is a single bone representing the developmental fusion of its five vertebral components. It is triangularly wedge-shaped, with its broad, thick proximal base, from which the thick lateral parts gradually diminish in size and taper to the distal apex (Fig. 564). The transversely flattened, posteriorly placed sacral canal runs throughout the length of the mass, and opens on the dorsal surface of the sacrum, somewhat proximal to its apex, at the sacrococcygeal hiatus. A series of openings lead directly anteriorly and somewhat laterally from the sacral canal. These are the anterior sacral foramina, through which the sacral nerves emerging from the cord may be reached in sacral anesthesia (Fig. 775). Posteriorly, at the entrance and exit of the canal are the lumbosacral and sacrococcygeal spaces, through which subarachnoid or extradural anesthesia, respectively, is induced.

The lumbosacral space is 1 cm. high and 2 cm. wide. The sacrococcygeal space, which is of an inverted V shape, is 2 cm. high and 1 cm. wide; it arises from the incomplete closure of the arch of the fifth sacral vertebra because of the absence of its laminae and spinous process. Both spaces are closed by resistant fibrous membranes. Sacral decubitus ulceration and infected abrasions of the skin in this region expose the sacral canal and its contents, and may result in neuritis, meningitis or myelitis. In embryonic development there may be incomplete closure of the canal posteriorly, exposing the canal contents as a hernia known as spina bifida.

The base of the sacrum presents the ordinary markings of a vertebra. In the midanterior portion of the base is a flat, slightly depressed, oval articular surface for the fifth lumbar vertebra. Posterior to the articular surface is the opening into the sacral canal. The thick, massive, lateral part of the sacrum represents the fusion of the transverse processes of the five sacral vertebrae (Fig. 564). Through that part of the sacrum which represents the fusion of the first, second and third sacral vertebrae there is articulation with the ilium. Fusion processes at the base of the sacrum present a variety of anomalies, such as a fused sixth lumbar vertebra or one fused on one side only. The lateral margins of the sacrum distal to the sacroiliac joint are thin and narrow, affording an expansive attachment to the stabilizing sacrotuberous and sacrospinous ligaments.

Each sacral vertebra develops from three primary centers, one for the body, and one for each half of the neural arch. These centers appear between the third and eighth months. In addition to the primary centers, there are

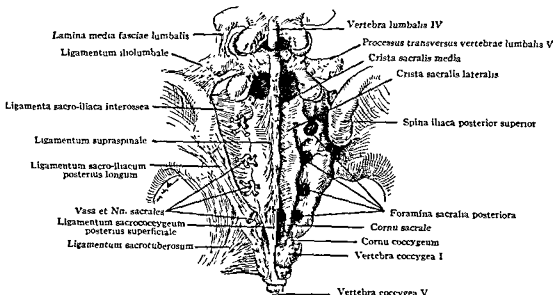


Fig. 564. POSTERIOR VIEW OF THE SACROCOCCYGEAL REGION.

On the right side the vessels, nerves and ligaments have been removed to indicate the topography of the sacral foramina.

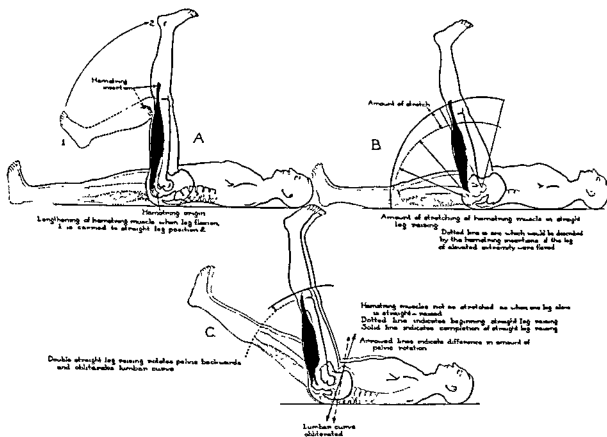


Fig. 563. EFFECT OF STRAIGHT LEG-RAISING UPON THE HAMSTRING MUSCLES, PELVIS AND LUMBAR SPINE. (Modified from M. Brahdy.)

Saccrococcygeal Region

SURFACE ANATOMY. The spinous processes of the sacrum, of which the second and third are the most prominent, may be palpated in the median line (Fig. 564). Following the median crest toward the base of the coccyx, two lateral bony prominences are palpated, the sacral and coccygeal cornua, which bound the sacral hiatus or external opening of the sacrococcygeal canal. The prominent posterior superior iliac spines may be palpated at the sides of the region. A line joining the posterior superior spines passes between the first and second sacral foramina and indicates the level of the termination of the subarachnoid space (p. 772).

The lateral crest of the sacrum, made up of the fused transverse processes of the sacral vertebrae, is one thumb-breadth lateral to the median sacral crest. The lateral crest, lying just to the outer side of the sacral foramina, serves as a landmark for injection through the foramina in extradural sacral anesthesia.

The pelvic surface of the sacrum and coccyx may be palpated through the rectum or vagina, a fact of considerable importance in determining the form and dimensions of the pelvis or the presence of irregularities which may be obstructive to parturition. Pelvic examination may reveal soreness along the sacral nerves emerging from the anterior foramina. The sciatic notch, through which the important pelvic nerves and vessels emerge to the thigh, also is palpable, and the presence of tumors or abscesses causing pressure on pelvic structures may be determined. Ordinarily the sacral promontory is not reached by the examining finger.

SOFT PARTS. The *skin* of the sacrococcygeal region is thick and resistant. It is bound down closely in the region of the anal crease, but generally is loose over the convexity of the sacrum. In emaciated or thin persons the bony prominences, otherwise well covered and protected, are brought into relief, and the overlying skin is subject to pressure ulceration (decubitus ulcer). The *musculoaponeurotic layer* over the sacrum is the inferior portion of the dorsal layer of the lumbodorsal fascia (p. 409), which covers and fuses with the expansive tendinous origin of the spinal musculature. It is attached to the median crest of the spinous

and urethra, and to the female bladder, urethra and vagina.

Surgical Considerations

SACRAL ANESTHESIA. The details of sacral anesthesia are outlined on page 775.

SACRALIZATION OF THE FIFTH LUMBAR VERTEBRA. The formula for the elements of the vertebral column is not fixed, and the process of shortening the lumbar spine is continuing. This is shown by the frequency with which the fifth lumbar vertebra takes on sacral characteristics. Lumbar sacralization implies fusion of the transverse processes of the fifth lumbar vertebra to the subjacent alae of the sacrum. Sometimes the lumbar transverse processes articulate with, or are fused to, the iliac crest through ossification of the iliolumbar ligament. Any of these conditions may cause persistent low back pain.

Fig. 565. CONSTITUENTS OF THE LUMBAR PLEXUS, SCHEMATIZED.

(From Haymaker and Woodhall: *Peripheral Nerve Injuries.*)

secondary nuclei fusing to form the massive lateral parts of the sacrum. These nuclei form the spinous processes and the two epiphysial plates of each sacral segment. The development of the sacrum is essentially the development of the separate segments which fuse into the adult bone by the twenty-fifth year.

The *coccyx*, the small, triangular, terminal segment of the spine, is made up of the distal four or five incompletely developed vertebrae joined to, and continuing in the direction of, the sacrum (Fig. 564). The whole coccyx may be ossified to the apex of the sacrum. The lateral margins of the coccyx and its tip continue the expansive origin of the sacrotuberous ligament and afford attachment to the muscles of the pelvic floor.

CONTENTS OF THE SACRAL CANAL. *The roots* of the lumbar, sacral and coccygeal nerves leave the cord in the lower dorsal and upper lumbar regions (Figs. 565, 566). The lowermost roots pass downward through the sacral canal, which contains the last five sacral nerves and the coccygeal nerves of each side, together with the terminal filament of the cord. The cul-de-sac formed by the dural and arachnoid membranes of the spinal cord occupies only the upper part of the canal, and usually does not descend below the level of the second sacral segment (Fig. 729), so that neither the dural tube nor its contained subarachnoid space is opened by a section traversing the bone below this level. An anesthetic for infiltration of the sacral and coccygeal nerves must be injected into the sacral canal distal to the blind ending of the dural cul-de-sac (Fig. 732, p. 774). Within the sacral canal lies also some loose fatty tissue traversed by numerous veins and by branches of the lateral sacral arteries.

The sacral nerves, after dividing into anterior and posterior branches, leave the canal *through their respective foramina.* Several of the sacral nerves are concerned directly in resection of the sacrum. The serious consequences attending destruction of the third and fourth sacral nerves are dependent upon the fact that they innervate both the anorectal region and the external anal sphincter through the inferior hemorrhoidal branch of the pudendal nerve (Fig. 566; compare Fig. 565). The nerve supply of the levator ani muscle is derived chiefly from the third, but partly from the second and fourth, sacral nerves, and the external sphincter receives an independent filament from the fourth sacral nerve through its perineal branch. The second, third and fourth sacral nerves are the *principal sources* of visceral branches to the male bladder, prostate

Fig. 566. CONSTITUENTS OF THE SACRAL PLEXUS, SHOWN SCHEMATICALLY.

(From Haymaker and Woodhall: *Peripheral Nerve Injuries.*)

M. psoas major
M. piriformis
Foramen suprapiriformis
Foramen infrapiriformis
M. levator coccygis
M. obturator internus
Arcus tendineus m. levatoris ani
Canalis obturatorius
M. levator ani
Symphysis pubis
M. bulbocavernosus
Diaphragma urogenitale
Pars membranacea urethrae
Intestinum rectum
M. transversus perinaei superficialis
M. sphincter ani superficialis

Fig. 567. MUSCLES OF THE LATERAL WALL AND FLOOR OF THE MALE PELVIS.

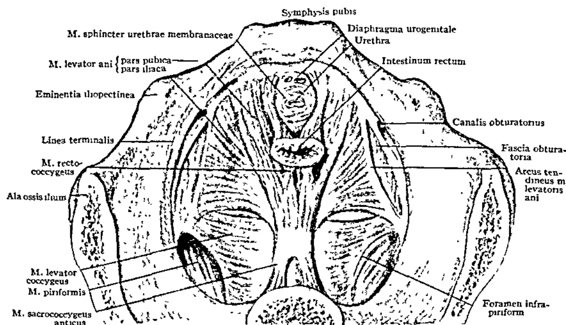


Fig. 568. MALE PELVIC DIAPHRAGM FROM ABOVE.

CHAPTER 17

Soft Parts Lining the Pelvis

The soft parts lining the pelvis include the muscles lining its walls, those forming the pelvic diaphragm, the fascia and peritoneum covering them, and the vessels and nerves.

PARIETAL MUSCULATURE, INTERMUSCULAR FORAMINA AND PARIETAL FASCIA. The obturator internus and piriformis muscles smooth out the contour of the true pelvis before entering the gluteal region through the greater and lesser sciatic foramina to insert on the femur (Figs. 567, 568).

The *obturator internus muscle* (L 4, 5; S 1) springs from the circumference of the obturator foramen and the medial surface of the obturator membrane, from which broad area of attachment the muscle bundles converge toward and almost fill the lesser sciatic foramen. The converging tendon is flanked by the gemelli muscles arising outside the pelvic cavity on the ischial spine and tuberosity. The composite muscle tendon bends about the margin of the foramen to insert on the medial surface of the great trochanter just above the trochanteric (digital) fossa. With this posteromedial insertion the obturator internus acts as an external rotator of the thigh.

Like the obturator internus muscle, the *piriformis muscle* (S 1, 2) arises on the osseoligamentous framework of the interior of the pelvis. It springs mainly from the anterior surfaces of the second, third and fourth sacral vertebrae lateral to the anterior sacral foramina, and, to a less degree, from the sacrotuberous ligament. Its fibers run outward and converge inferiorly into a musculoaponeurotic tendon which leaves the pelvis by the greater sciatic foramen (p. 572). The piriformis does not occupy all the cavity of the greater foramen, but leaves two areas comparatively open, one above and one below the muscle (Fig. 567). These openings are the suprapiriform and infrapiriform spaces or foramina.

The *suprapiriform foramen* is bounded above by the greater sciatic notch and below by the upper margin of the piriformis muscle, furnishing a passage for the superior gluteal vessels and nerves from the pelvis to the gluteal region (p. 923). The *infrapiriform foramen*, bounded by the lower border of the piriformis muscle above and by the ischial spine and sacrospinous ligament below, is traversed by pelvic vessels, the sciatic nerve and the nerves running to the perineal region. These openings and the obturator canal (Fig. 579) are areas of lessened resistance, through which intrapelvic structures may herniate.

The *parietal pelvic fascia* clothing the obturator internus and piriformis muscles is fused densely with the sheaths of the vessels and nerves which emerge through the foramina. A reinforced area termed the tendinous arch, or linea terminalis, extends backward from the posterior surface of the pubis to the spine of each ischium, and serves as the line of origin for the levator ani muscles (Figs. 567, 622 to 624).

PELVIC DIAPHRAGM. The outlet of the pelvis is closed by a concave musculoaponeurotic hammock, the pelvic diaphragm (Figs. 567, 568, 571; *cf.* Figs. 619, 620, 622, 623). The main pelvic or muscular diaphragm, consisting of the paired levator ani and coccygeus muscles, is incomplete anteriorly. Beneath the levators is situated the *urogenital diaphragm;* this diaphragm is stretched across the subpubic arch and is densely adherent to the under surface of the mesial borders of the separated levators (Fig. 567; *cf.* Figs. 617 to 619).

Each *levator ani muscle* (N. pudendal, S 3, 4) is composed of a lateral and a mesial portion (Figs. 567, 568). The lateral portion arises from the posterolateral aspect of the body of the pubis and from the linea terminalis of the parietal pelvic fascia. Its fibers run obliquely

downward and backward, without adhering to the prostate, vagina or lateral surface of the rectum, to form the anococcygeal raphe. The mesial or pubococcygeal portion arises from the pubic body nearer to the median line than to the lateral segment. It is directed posteriorly along the lateral surface of the prostate or vagina, and, after entering into the composition of the central tendinous area of the perineum, blends with the longitudinal muscle of the rectum near the anal margin (p. 594). The *coccygeus muscle* (S 3, 4), which completes the main pelvic diaphragm behind, overlies the sacrospinous ligament and extends fanwise from the spine of the ischium to the coccyx. It lies immediately inferior to the piriformis muscle. The *visceral layer* of the *pelvic fascia* is that which overlies the pelvic surface of the muscular diaphragm.

The pelvic diaphragm has the unique and important function of supporting much of the weight of the superimposed viscera when the body is erect. Hernias through the diaphragm, such as prolapse of the bladder and rectum and descent of the uterus, are frequent (Fig. 579).

EXTRAPERITONEAL SPACE OF THE PELVIS; PELVIC PERITONEUM. A commodious *extraperitoneal space* separates the pelvic diaphragm from the pelvic peritoneum (Fig. 600). It contains areolar tissue which is in communication with the gluteal and obturator regions. Extraperitoneal pelvic abscesses may progress upward into the iliac fossae and anterior abdominal wall. In the extraperitoneal space lateral rectal, retrorectal and retrovesical compartments are differentiated.

The *pelvic peritoneum* is lifted into folds and depressed into culs-de-sac by the bladder, rectum and pelvic genitals. The peritoneum is depressed into lateral recesses about the rectum and into a deep cul-de-sac (of Douglas), which separates the rectum from the urogenital organs and descends to within 6 or 7 cm. of the perineum. In the male the cul-de-sac descends just below the level of the seminal vesicles. In the female the rectouterine pouch (p. 637) is bounded laterally by the uterosacral ligaments, which divide it into two parts. The upper and broader division is in relation to the posterior surface of the uterus, and the inferior and narrower division, to the posterior fornix of the vagina.

VESSELS AND NERVES. The pelvic vessels and nerves, all of which run in the extraperitoneal cellular spaces, are known as parietal or visceral, according to whether they supply the soft parts of the pelvic walls or are distributed to the pelvic viscera (Fig. 571).

The HYPOGASTRIC ARTERY, a branch of the common iliac, is the main artery of both the interior and exterior of the pelvis. It runs mesial to the psoas muscle along the sacroiliac joint line and descends almost vertically into the pelvis. After the iliolumbar and lateral sacral arteries are given off, the hypogastric artery divides, at the upper margin of the greater sciatic foramen, into a posterior trunk and a smaller anterior trunk.

Of the *parietal branches*, the superior gluteal artery is the continuation of the posterior division of the hypogastric artery, and is distributed to the gluteal region of the hip through the suprapiriform space (Fig. 571). The anterior division of the hypogastric artery, in addition to giving off the obturator, inferior gluteal and internal pudendal branches, is the main arterial supply of the pelvic viscera. The inferior gluteal and internal pudendal branches leave the pelvis through the infrapiriform space (Fig. 571), and the obturator artery leaves the pelvis through the obturator foramen (Fig. 571). Frequently the obturator artery arises from the inferior epigastric artery, crosses the femoral canal, and becomes of surgical interest in the operation for femoral hernia (Fig. 902).

All the *visceral branches* to the pelvic contents are derived from the anterior trunk of the hypogastric artery (Fig. 571). They have a certain degree of mobility necessitated by the changing conditions in the uterus, bladder and rectum. This mobility is facilitated by the investment of these vessels in a large amount of lax extraperitoneal connective tissue. Groups of branches supply the bladder, genitals and rectum, and are described with the viscera to which they are distributed.

The visceral and parietal VEINS form rich anastomotic plexuses, the efferent trunks of which are directed to the hypogastric vein.

The anterior divisions of the sacral and coccygeal NERVES form the sacral and pudendal plexuses (Fig. 566). The *sacral plexus* is formed by the anterior divisions of the fourth and fifth lumbar and the first, second and third sacral nerves. These nerves lie largely on the mesial surface of the piriformis muscles and form a marked thickening on the pelvic wall which is

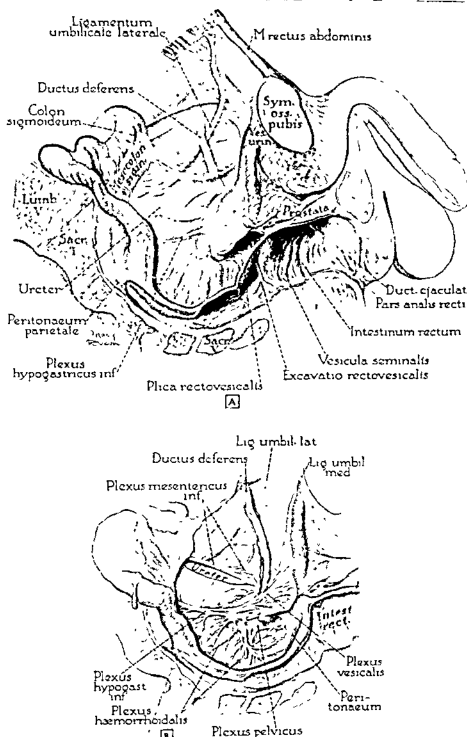


Fig. 569. PELVIC AUTONOMIC NERVES AND RELATED STRUCTURES IN THE MALE; 4 SUCCESSIVE LEVELS, FROM PERITONEUM TO PARIETAL MUSCULATURE.

A, Topography of the hypogastric plexus and related pelvic structures in a hemisected specimen; peritoneal level. The retroperitoneal position of the plexus is evidenced as a low elevation in the serous layer. *B*, Topography of the plexuses, ureter and ductus deferens; immediately subperitoneal level. Showing the structures related to the pelvic colon and rectum; namely, ureter, bladder, ligaments and nerves. The parietal peritoneum of the lesser pelvis has been removed and, additionally, the vesical part of the visceral peritoneum. The serous layer remains as the pelvic mesocolon, the covering of the colon and rectum, the rectovesical fascia and also as the bilaminar septum which descends between the bladder and rectum (fascia of Denonvilliers; marked by arrow here and in *a*). The ureter, ductus deferens, umbilical ligament (obliterated artery) and nerves have been freed from the thin stratum of subperitoneal areolar tissue. (From Ashley and Anson: Surg., Gynec. & Obst., 82: 598–608, 1946.)

overlaid by the pelvic vessels. The nerves converge toward the lower part of the greater sciatic foramen (infrapiriform space), and unite to form a flattened band which is continued as the sciatic nerve into the gluteal region. The inferior gluteal nerve leaves the pelvis through the infrapiriform space of the greater sciatic foramen to supply the gluteal musculature.

The *pudendal plexus* is not marked off sharply from the sacral plexus. It is formed usually by branches from the anterior division of the second and third sacral nerves, all the anterior division of the fourth and fifth sacral nerves, and the coccygeal nerve; it lies on the posterior wall of the pelvis. Its main branch, the pudendal (internal pudic, ischiadic) nerve (Fig. 566), leaves the infrapiriform space, enters the gluteal region, and terminates by supplying the external genitals and much of the perineum.

The obturator nerve from the lumbar plexus runs along the mesial margin of the psoas muscle, the sacroiliac joint and the linea terminalis, and enters the obturator foramen *en route* to the adductor region of the thigh (Fig. 570, *B*).

Surgical Considerations

The autonomic nerves of the pelvis make up a set of neural sheets which not only are of gross dimensions, but also are of such position and form as to be demonstrable in the form of subperitoneal bands with predictable relationships to bony landmarks, to large blood vessels and to viscera. The large bands and the lesser contributory fibers, as they course from root or plexus of origin to area of visceral termination, are either lodged within readily dissectable fibrous laminae or situated at levels either immediately superficial or deep to such laminae.

The chief layer is that which is most marked as it extends upward along the pelvic wall after having formed a strong sheath for the urinary bladder and associated structures. It is the layer which transmits, also, the blood vessels of visceral supply. Resting upon this stratum, at subperitoneal level, is an areolar tissue in which is situated most of the nerves of supply to the rectum; under the same stratum are placed the sacropudendal plexus and the rami which pass therefrom to the large plexus in the intermediate layer. The intermediate is, therefore, the chief one of the three; into the pelvic plexus which it contains pass rami from the sympathetic and parasympathetic plexuses in layers on its internal and external aspects.

In the superficial (internal) layer of areolar tissue course the hypogastric plexus, that portion of the pelvic plexus which sends rami chiefly to the rectum, the contributory mesenteric plexus, and the ductus deferens. These are structures which are subperitoneal or were originally mesenterial (when, embryonically, a mesorectum existed). Being placed immediately beneath the serous lining of the pelvic cavity, they elevate the peritoneum but less markedly than do the umbilical ligaments (Fig. 569, *A*).

Topographically, the inferior mesenteric plexus lies anterior to the ureter, following it closely; the inferior hypogastric plexus and its pelvic prolongation lie posterior to the ureter, between the latter and the rectum. The main mass of the plexus courses in a curving line—concave anteriorly—between the first piece of the sacrum and the rectovesical fold.

In its distal portion the fibers spread out principally on the superior surface of the bladder; behind, groups of fibers radiate to the rectum, a strong set forming a secondary plexus close to the rectal wall. Altogether, these plexuses and derived fibers of visceral supply cover a semicircular area whose posterior boundary follows the contour of the rectum and that of the sacrum against which the latter rests (Fig. 569, *B*).

Embedded in the heavy layer of true retroperitoneal tissue are the deeper elements of the autonomic supply (Fig. 570, *A*). The anterior boundary of this set of fibers coincides with that of the more superficially situated hypogastric plexus, but its form is strikingly different. It assumes the configuration of a broad ribbon, wider at the proximal and distal ends than in the middle two fourths of its extent. Its widest portion is proximally situated, where visceral rami are contributed by the sacral nerves (Fig. 570, *A*); upon it converge, distally, the fibers of the vesical portion of the pelvic plexus, to produce a second broadening; terminal distribution to the bladder, prostate, seminal vesicles and rectal ampulla is also instrumental in causing the widening of the band which occurs at its antero-inferior end. In an anteroposterior direction this intermediate band is somewhat more extensive than the superficial; the former is carried to the sacrum

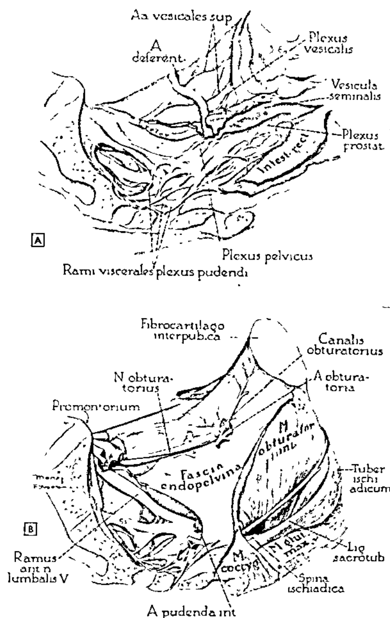


Fig. 570. PELVIC AUTONOMIC NERVES; DISSECTION CONTINUED.

A, Form and composition of the deeper leaf of nerves. Showing the pelvic plexus, the superficial leaf of which has been entirely removed to expose the deep layer of the pelvic autonomic plexus and the nerves contributing to its fabric. The nerves from the second to fourth sacral (erigens) remain intact, and the anterior continuation of the pelvic autonomic plexus has been followed ventralward to the bladder, seminal vesical and prostate. The rectum, transected at coccygeal level, has been retracted. The superficial group of vessels is exposed (superior and middle vesicular arteries from the obliterated hypogastric); the deep vessels (hypogastric and external iliac) remain covered by the heavy lamina of pelvic fascia. The main mass of the plexus is parietal in position, resting upon tissue which, in turn, lies immediately upon the obturator fascia. *B*, Sacral plexus with derivative parasympathetic fibers (cut), and parietal and related diaphragmatic muscles and fasciae. Viscera and autonomic plexuses have been removed. The greater portions of the larger vessels have also been removed, leaving only their proximal and distal ends. The obturator nerve is exposed throughout its course. The sacral plexus has been followed to its point of exit through the greater sciatic foramen (i.e., to point of convergence of the trunks to form the sciatic and pudendal nerves) The parietal portion of the endopelvic fascia is fully exposed; the levator ani muscle has been cut close to its origin along the tendinous arch, where the levator fibers are shown by trimming away the superior fascia of the pelvic diaphragm. The ischiorectal fossa has been freed of fat to reveal the pudendal artery (other associated vessels and nerves removed), obturator internus muscle, sacrotuberous ligament and gluteus maximus muscle. (From Ashley and Anson: Surg., Gynec. & Obst., 82: 598–608, 1946)

CHAPTER 18

Pelvic Viscera in the Male

The viscera which occupy, and are fixed to, the floor and walls of the male pelvis are the rectum, bladder, prostate, pelvic ureters, seminal vesicles and deferent ducts (Fig. 589). Loops of ileum, the sigmoid colon, and occasionally the appendix are distinguished from the intrinsic contents of the true pelvis on the basis of their fixation to the walls of the abdomen and the false pelvis. The musculature of the pelvic wall and diaphragmatic floor is fundamentally similar in both sexes. In the female the uterus and vagina are interposed between the urinary bladder and the rectum (Fig. 571); in the male the uterus is represented by the prostatic utricle (*uterus masculinus*), which, as a short cul-de-sac, courses upward and backward in the substance of the prostate, behind the middle lobe. Branches of the external iliac artery, and the corresponding veins, are of matching origin and course in male and female. Among the branches of the hypogastric division of the common iliac artery, the uterine may be regarded as a branch added to the male series, whereas the vaginal artery (Fig. 571) may be considered, developmentally, as the equivalent of one of the inferior vessels.

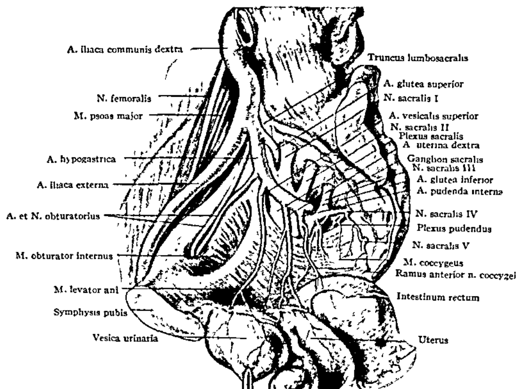


Fig. 571. LATERAL VIEW OF THE FEMALE PELVIS TO SHOW THE MAIN ARTERIES AND NERVES. The bladder, rectum and the pelvic genitals are drawn downward to show their arterial supply.

(the points of origin of the nerves, Fig. 570), the latter to the rectum (the visceral area of supply). The intermediate band is the longer of the two, owing to the fact that the greater bulk of its fibers is supplied, not to the rectum in the sacral curve, but to the bladder, prostate, anal canal, as these rest upon the pelvic floor.

The third and deepest of the three neural strata is that composed of the proximal portions of the visceral rami of the pudendal plexus and the sacral plexus, from which the rami are derived (Fig. 570, *B*). Because the branches quickly enter the pelvic plexus—merging, on the latter's deep aspect, and within the substance of the heavy retroperitoneal tissue—this third layer is but slightly longer than it is wide. It overlies the second to fourth nerves (from which it arises); being thus caudally placed, its long axis is at almost a right angle to that of the hypogastric plexus in the superficial, or first, layer. The upper cords of the sacral plexus, and the lumbosacral cord from the abdominal level, rest in similar tissue upon the piriformis muscle; the pudendal rami leave the nerve trunks near the point where the latter emerge through the greater foramen *en route* to the gluteal region. As the rami course toward the pelvic plexus, they come to lie upon the fascia covering the obturator internus.

The sympathetic fibers which descend into the pelvis from abdominal level form the mesenteric and hypogastric plexuses; the parasympathetic fibers, commonly described as forming a nervus erigens, enter the pelvic plexus as a set of anastomotic nerves. All fibers, so far as gross examination reveals, are mixed in the broad ribbon of nervous tissue which is termed pelvic plexus. Therefrom fibers stream toward the several pelvic organs, a degree of stratification existing in the distribution of mesenterial and to retroperitoneal viscera: for the most part, nerves to the rectum pass, on immediately subperitoneal, or superficial, level, from the anterior border of the plexus backward, in radiating fashion, to the pelvic portion of the digestive tube; similarly, nerves to the urinary bladder, subjacent prostate gland, to the seminal vesicles, lodged, at the intermediate level in the heavy sheath of retroperitoneal tissue, stream downward and forward to the organs named—all ultimately supported by the funnel-shaped pelvic diaphragm.

From the surgical standpoint the following conclusions seem warranted: Sympathetic fibers may be transected by presacral neurectomy, parasympathetic elements left untouched by the same procedure; in both abdominal and perineal approach to the rectum (in high operation for carcinoma) the chief portions of the autonomic plexuses are removed, by safe distance, from the surgical field—being parietal in position in the dorsal portion of the pelvic cavity; in any of the regular approaches (pubic, transsymphysial, perineal or rectal) to the urinary bladder or prostate gland the disturbance of tissue would occur in areas where concentration of autonomic fibers is minimal—behind the main plexiform aggregations in anterior approach, and above them in inferior entrance to the pelvis. However, in wide removal of carcinomatous lymphatic and associated fibrous tissue within the pelvis, the areas where nerves are abundant would be affected; the plexuses, in resting upon the hypogastric artery and its important branches, are situated between the peritoneum and the lymphatics, since the latter are closely associated with the blood vessels.

Ligation of the Common Iliac Artery. On the right side the vessel is not overlaid by any structures of importance, although the ureter is close by. The vena cava and both common iliac veins are in close relation to the artery on this side. The common iliac vein passes deep to the artery. On the left side the sigmoid mesocolon, containing the sigmoid and the superior hemorrhoidal branches of the inferior mesenteric artery, covers almost all the common iliac artery. The common iliac vein usually lies somewhat behind and mesial to the artery.

The approach in the *extraperitoneal exposure* is through a transverse incision (Fig. 552). The abdominal muscles and transversalis fascia are divided, and the peritoneum is lifted away from the iliac fascia along the line of the direction of the iliac crest. The peritoneum must be pressed forward away from the psoas muscle and the iliac vessels lying along the mesial margin of that muscle. The ureter remains attached to the peritoneum and with it is lifted out of danger.

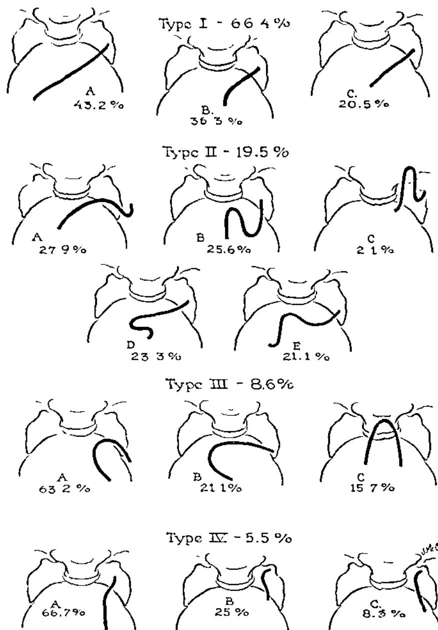


Fig. 573. SIGMOID MESOCOLON. VARIATIONS IN FORMS, LENGTH AND POSITION OF THE LINE OF CONTINUITY WITH THE PARIETAL PERITONEUM. DIAGRAMMATIC.

Major types (I to IV) are illustrated, together with subsidiary variations. The percentage occurrence of each type and subtype is recorded, based upon an examination of 220 specimens.

As determined by a recent study of 220 specimens, the line of mesenteric attachment of the sigmoid colon is more likely to be straight or slightly curved (*I A* to *I C*) than to be sharply curved, V-shaped or sinuous. When the line of dorsal peritoneal continuity is sinuous, the S-shaped form may be that of a widely open letter S (*II A*), one of typical form, but altered plane (*II B*), or compressed centrally (*II C*) or at its distal end (*II D*, *II E*). Less frequently the mesenterial attachment assumes the form of an inverted letter U (*III A* to *III C*). Least often the line of attachment is vertical (*IV A* to *IV C*); in such cases, in the present series, the deflection is markedly to the left of the midline with the attachment in some instances largely sacral (*IV B*). (From Cleveland and Anson: Unpublished study.)

Sigmoid Colon and Rectum

Definition, Boundaries and Divisions. The sigmoid colon (pelvic colon or sigmoid flexure) usually forms a loop approximately 40 cm. in length, and typically lies within the pelvis. However, owing to its mobility through mesenterial attachment, its position and configuration are variable (Fig. 572). The supporting mesentery, the sigmoid mesocolon, is likewise variable in length and in disposition in relation to the sacrum and the innominate bone (Fig. 573).

The rectum, or terminal portion of the large intestine, begins anterior to the body of the third sacral vertebra and, after traversing the pelvic floor, terminates at the anus. It is customary to divide the rectum into the pelvic rectum and the perineal or anal rectum.

The pelvic rectum lies within the pelvic cavity and is from 12 to 14 cm. in length. At its beginning it usually lies in the median line,

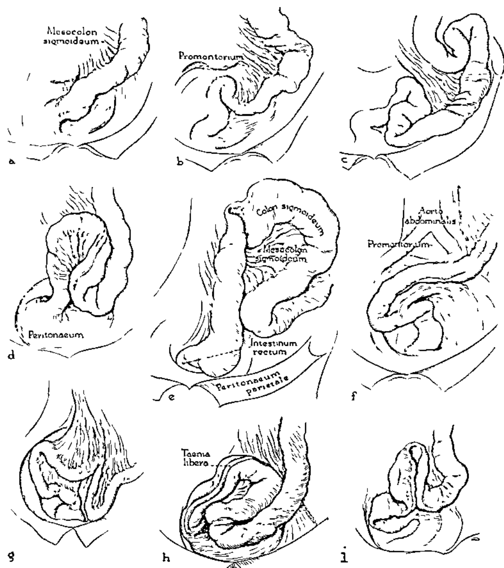


Fig. 572. SIGMOID COLON AND SIGMOID MESOCOLON. SELECTED EXAMPLES TO DEMONSTRATE VARIATION IN FORM AND POSITION.

a, An example of short mesocolon with the colon passing directly from the left iliac fossa to a median position in front of the third piece of the sacrum (there to become continuous with the rectum). *b* and *c*, Examples of sigmoid mesocolon of typical length; in each instance the mesenterial segment of the large intestine occupies the left iliac fossa. *d* and *e*, Specimens with sigmoid colon of true S-shaped configuration; the redundant loop ascends into the abdominal cavity. *f* and *g*, Cases in which the sigmoid colon, although looping toward the right, lay caudal to the elevation, along the pelvic brim, produced by the external iliac vessels (that is, mainly within the cavity of the lesser pelvis). *h* and *i*, Additional examples of pelvic colon with true S-shaped form; differing from the specimens pictured as *d* and *e* chiefly in regard to the length of the mesenterial segment of the colon. (From Cleveland and Anson: Unpublished study.)

nounced nonfusion there may be an intestinal hernia into the perineum. A deep rectovaginal pouch may allow an intestinal loop to press into the vagina as a vaginal enterocele, or cause a perineal hernia.

When the rectum is filled, two peritoneal folds pass from the lateral walls of the bladder to the ampullary portion of the rectum, and bound the entrance to the lowermost cavity of the pelvic peritoneal pouch. These rectovesical folds or ligaments (of Douglas) contain smooth muscle fibers which give them a supporting role in the fixation of the bladder (Fig. 569, *A*). Morphologically, these folds are analogous to those which unite the uterus to the rectum and sacrum (uterosacral ligaments).

The extraperitoneal portion of the rectum is in relation to that part of the base of the bladder lying between the deferent ducts (interdeferent triangle, or rectovesical trigone) through the intermedium of the rectovesical fascia of Denonvilliers (Fig. 569, *A*, *B*). This frontally placed aponeurosis or septum offers no obstacle to digital examination of the prostate and seminal vesicles through the rectum, but explains why carcinoma of the rectum invades anterior structures only in late stages.

DEVELOPMENT AND CONGENITAL MALFORMATIONS. In early embryonic life the terminal segment of the intestine and the bud which forms the primitive bladder and urethra constitute a single cavity, the *cloaca*, which is separated from the exterior by the *cloacal membrane* (Fig. 574). The cloaca is transformed gradually into two cavities by the downgrowth of a frontally placed partition, the *urorectal septum*. The ventral space represents the urogenital sinus, and the dorsal space forms the rectum. The cloacal membrane is not broken through to the outside until the urorectal septum has divided the cloaca. The anal portion of the cloacal membrane, which separates the rectum from the surface, breaks through first, forming the anal orifice. The urogenital sinus opens through the urogenital part of the membrane into the urethral orifice in the male; in the female the urogenital sinus opens into the urethrovaginal orifice.

Various *congenital malformations* occur as a result of failure of these parts to develop properly (Figs. 575 to 577). The most frequent anomaly is anal atresia, which results from failure of the anal portion of the cloaca to open to the exterior through the cloacal membrane. Abnormal union may occur between the rectum and the urogenital sinus, and the rectum may open into the anterior urogenital structures. The rectum may be absent or may open externally by a narrow fistula. The terminal rectum and the vagina may be connected by a fistula. The prognosis in these malformations depends upon the variety. Imperforations are fatal in a few days unless a permanent outlet is established.

VESSELS. The *arteries* forming the rich anastomoses in the rectum are the superior, middle

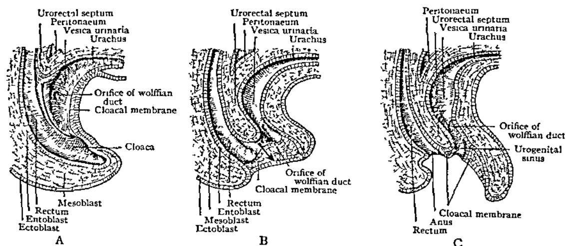


Fig. 574. DIAGRAM OF THE DEVELOPMENT OF THE RECTUM, ANUS AND BLADDER.

In *A* the arrow indicates the direction of growth of the uro(ano)rectal septum toward the cloacal membrane. *B*, The urorectal septum has almost partitioned the cloaca into vesical and rectal compartments. *C*, The urorectal septum has reached the cloacal membrane, which has given way at the caudal termination of the bladder and rectum; separate exits are formed for these structures.

and, in its downward course, describes a curve corresponding closely to that of the sacrum and coccyx. At its lower level the puborectal portion of the levators (p. 584) comes into contact with its lateral surfaces. This level lies at the apex of the prostate in the male, and opposite the lower fourth of the posterior vaginal wall in the female. Description of the anal rectum properly belongs in the section on the perineum (p. 698). The pelvic rectum, especially when distended, presents a series of lateral foldings or inflections which produce horizontal, shelflike projections within the bowel. These projections, the rectal valves (of Houston), partially divide the rectum into a series of compartments. The lumen of the rectum is not uniform, but is narrow at its upper and lower extremities. Toward the lower portion of the bowel the lumen expands to form the rectal ampulla. The anterior wall of the ampulla bulges and angulates forward and downward immediately proximal to the anal canal. This bulging is particularly marked in women who have borne children and in subjects with a relaxed pelvic floor. In the male the ampulla projects forward almost to the apex of the prostate and to the membranous urethra. The attachment of the rectourethralis muscle to the ampulla of the rectum and to the superior fascia of the urogenital diaphragm (p. 693) causes this anterior angulation of the bowel. The bowel must be avoided when the muscle is divided in perineal prostatectomy. The varied pathologic changes of the pelvic rectum and the numerous surgical interventions designed to cope with them give this division unusual clinical and topographic interest.

Location and Attachments. The sigmoid colon begins, typically, at the superior aperture of the lesser pelvis (where it is continuous with the iliac segment of the colon), and passes transversely across the sacrum to the right side of the midline. Then, curving on itself, the sigmoid colon turns toward the left, reaching the middle line at the level of the third piece of the sacrum (see variations, Figs. 572, 573).

The rectum lies in the midst of the areolar tissue of the pelvic extraperitoneal space. Extraperitoneal tissue separates the anterior surface of the rectum from the posterior surface of the seminal vesicles and prostate. Cellulitis may develop in the prerectal tissue as a result of lesions in the prostate, seminal vesicles or bladder, but it arises more frequently from lesions of the rectum. Inflammatory processes in the region may burrow into the rectum or may perforate the levator ani muscle and point in the ischiorectal fossa.

The rectum is maintained in position by the peritoneum, which incompletely surrounds its upper part, by sheaths from the visceral division of the pelvic fascia, and by lateral fibrous prolongations carrying the middle hemorrhoidal vessels. The firm adhesion of the rectum to the levator ani muscles forms a fixed point of attachment. Each rectal support must be freed in extirpation of the viscus. When the elements holding the rectum in position become lax, rectal prolapse tends to occur (p. 707).

Relations. The sigmoid colon is related posteriorly to the external iliac artery and vein, the piriformis muscle and the sacral plexus of nerves of the left half of the pelvis. Anteriorly it is separated from the urinary bladder in the male, and the uterus in the female, by some of the coils of the jejuno-ileum.

The rectum rests upon the sacrum, coccyx and middle sacral artery, and is separated from them by the visceral layer of pelvic fascia and by extraperitoneal connective tissue. The extraperitoneal relationships form the rationale for the sacrococcygeal approach to the rectum. The close relation of the rectum to the lumbosacral plexus explains the sciatic and perineal distribution of pain noted at times as an early symptom of carcinoma of the rectum (Figs. 569, *B*; 570, *B*).

The peritoneum covering the apposed surfaces of the rectum and bladder forms the rectovesical cul-de-sac (of Douglas), which extends to the uppermost margin of the rectovesical fascia bridging the extraperitoneal portions of the rectum and bladder (Fig. 569, *A*). Not all the posterior aspect of the bladder has a peritoneal covering, for the peritoneum usually descends only to within 1 cm. of the base of the prostate. Only the anterior and lateral surfaces of the upper two thirds of the rectal ampulla receive a peritoneal investment. In the newborn this peritoneal pouch descends until it clothes all the posterior surface of the bladder, seminal vesicles and a part of the posterior surface of the prostate. It sometimes reaches the pelvic diaphragm. Adults may manifest the persistence of fetal conditions as a consequence of lack of fusion of the two embryonic layers of the pouch which lie in contact. In pro-

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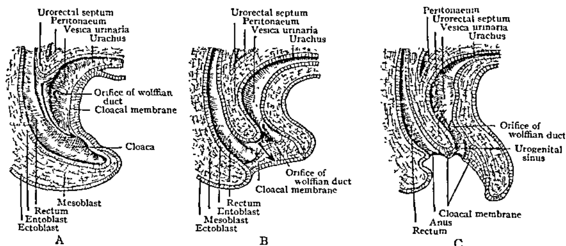


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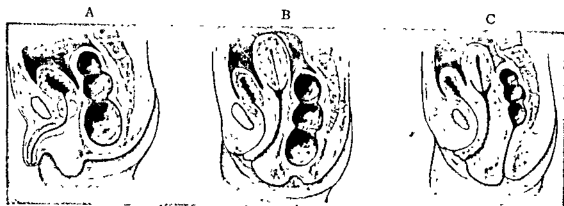


Fig. 575. ANOMALIES IN THE DEVELOPMENT OF THE PELVIC AND ANAL PORTIONS OF THE RECTUM.

A, Complete absence of the anus; *B*, failure of the pelvic rectum to connect with the anal depression; *C*, the terminal part of the pelvic rectum and the anal canal are greatly narrowed.

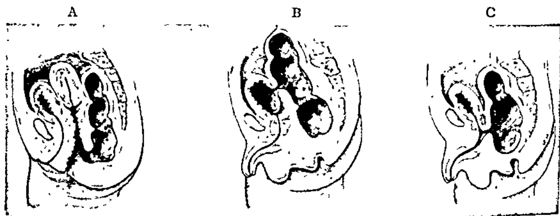


Fig. 576. ANOMALIES IN THE DEVELOPMENT OF THE RECTUM AND THE UROGENITAL APPARATUS.

A, The pelvic rectum opens into the vagina; there is complete absence of the anal canal. *B*, The pelvic rectum opens into the bladder; parts of the anal canal and terminal pelvic rectum are absent. *C*, The pelvic rectum opens into the male urethra; parts of the anal canal and terminal pelvic rectum are absent. These conditions are known as atresia ani vaginalis, atresia ani vesicalis, and atresia ani urethralis.

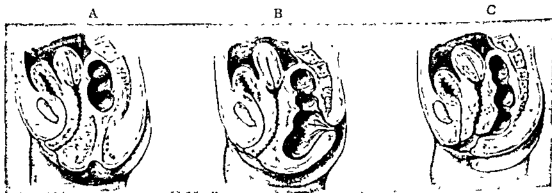


Fig. 577. ANOMALIES IN THE DEVELOPMENT OF THE RECTUM AND UROGENITAL APPARATUS.

A, The anorectal tract is impervious and fibrous; *B*, the pelvic rectum opens just below the coccyx; *C*, there is a cloaca formation in which the bladder, vagina and rectum open into a common cavity.

and inferior hemorrhoidals and the middle sacral. The middle and inferior hemorrhoidal arteries are bilateral vessels with a symmetrical arrangement. The superior hemorrhoidal and middle sacral arteries are single.

The superior hemorrhoidal artery is the direct continuation of the inferior mesenteric artery into the pelvis (Fig. 515). After crossing the left common iliac artery, it runs downward between the layers of the pelvic mesocolon near their parietal attachment. Upon reaching the rectum the artery usually bifurcates into right and left divisions, both of which are surrounded by a layer of areolo-adipose tissue lying between the rectal fascia and the bowel wall. Its branches spread over the rectum posteriorly, laterally and anteriorly.

The middle hemorrhoidal artery usually is represented by two or more branches which originate either in the trunk of the hypogastric artery (Fig. 619, p. 638) or in one of its larger branches, the internal pudendal or the inferior vesicular.

The inferior hemorrhoidal artery is distributed to the perineal rectum (Fig. 619). It arises on each side from the internal pudendal artery in Alcock's canal in the ischiorectal fossa. It supplies sufficient blood to nourish a rectal stump in anterior resections of the rectum. The middle sacral artery arises from the abdominal aorta near its termination and runs downward in the median plane on the posterior surface of the rectum, to which it supplies a few twigs.

The *rectal veins* differ from those of the other divisions of the large bowel in that they form a rich hemorrhoidal plexus within the thickness of the bowel. This plexus is developed best in the anal region. The superior hemorrhoidal vein is tributary to the portal system, but the middle and inferior hemorrhoidal veins drain to the inferior vena cava.

The *venous spread of carcinoma of the rectum* is thought to begin in the tumorous intestinal wall and adjacent perirectal tissue. It certainly accounts for some local recurrence and metastasis to the liver, and its extent varies directly with the degree of differentiation of the primary tumor. Of interest is the fact that blood vessel invasion does not always mean distant metastases. In Brown and Warren's study* of 170 rectal carcinomas with complete postmortem findings, 33 per cent of the cases with intravascular tumor growth locally had no coexistent visceral metastases. Also, 34 per cent of their cases with visceral metastases had negative lymph nodes. Lymphatic channels are important, but are not the only method of carcinomatous spread. The surgeon must be cognizant of both routes when doing resections for carcinoma.

* Brown and Warren: Surg., Gynec. & Obst., 66: 611–21, 1938.

Lymphatic Drainage. This subject is of special interest to the surgeon because the rectum and rectosigmoid area constitute the most frequent site of carcinoma of the colon (Figs. 578, 593).

The commonly used abdominoperineal resection for carcinoma of the rectum was established by Miles of England as a result of a study on the lymphatic spread in hundreds of cases (Fig. 578); similar studies have been done in this country by Gilchrist and David, Coller and associates, Grinnell, Glover and Waugh, and others.* The essential findings of these workers demonstrated the lymphatic spread to the rectum.

A rich lymphatic plexus begins in the mucosa and extends throughout the submucosal and muscular layers, the main channels passing largely outward and not longitudinally along the course of the bowel. From the anal canal, drainage is to the inguinal nodes. The next highest portion, about the insertion of the levator ani muscles, has two paths of flow: (1) upward to the nodes about the superior hemorrhoidal vessels, and (2) laterally along the levator ani muscles to the obturator nodes and the ischiorectal fossa. Coller and associates found that the only malignancies showing this lateral spread were those arising between the mucocutaneous junction and a point 3 cm.

* Miles: Cancer of the Rectum: London, Harrison & Sons, 1926; Gilchrist and David: Lymphatic Spread of Carcinoma of the Rectum. Ann. Surg., 108: 621–42, 1938; A Consideration of Pathological Factors in Influencing Five-Year Survival in Radical Resection of the Large Bowel and Rectum for Carcinoma. Ann. Surg., 126: 421–35, 1947; Prognosis in Carcinoma of the Bowel. Surg., Gynec. & Obst., 86: 359–71, 1948; Coller, Kay and MacIntyre: Regional Lymphatic Metastasis of Carcinoma of the Rectum. Surgery, 8: 294–311, 1940; Grinnell: The Lymphatic and Venous Spread of Carcinoma of the Rectum. Ann. Surg., 116: 200–16, 1942; The Lymphatic Metastases of Carcinoma of the Colon and Rectum. Ann. Surg., 131: 494–506, 1950; Glover and Waugh: The Retrograde Lymphatic Spread of Carcinoma of the Rectosigmoid Region. Surg., Gynec. & Obst., 82: 434–48, 1946; Waugh and Kirkland: The Importance of the Level of the Lesion in the Prognosis and Treatment of Carcinoma of the Rectum and Low Sigmoid Colon. Ann. Surg., 129: 22–3, 1949.

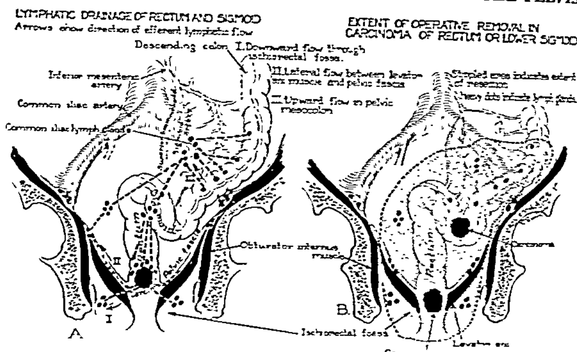


Fig. 578. LYMPHATIC DRAINAGE FROM THE RECTUM AND SIGMOID.

A, The lines of lateral and upward spread are designated. *B*, The area of excision for the Miles abdominoperineal resection of the rectum and sigmoid for carcinoma. (After Miles.)

More extensive upward dissections are continually being done in the effort to remove more lymph node-bearing tissue.

above it. Studies of lateral spread, however, have not been as satisfying as needed because of the small amount of tissue available. It has been stated by some writers and refuted by others that patients with tumors below the peritoneal reflection, where lateral spread is possible, do not have as high a five-year survival rate as those with tumors above that level.

From the midrectum upward the lymph flow is along the superior hemorrhoidal vessels to nodes about the bifurcation of the aorta. Further extension includes nodes about the aorta and inferior mesenteric vessels (Figs. 522 to 525). Gilchrist and David emphasized the concept that the lymphatic spread is primarily embolic and that the nodes where the emboli lodge prevent further spread until completely overwhelmed by cancer. Each node involved blocks that particular lymph channel, thus making it more difficult for new emboli to travel along that route.

The downward lymphatic spread of carcinoma of the rectum is an important point in consideration of any operation to conserve the sphincters. Glover and Waugh reviewed the literature on the incidence of retrograde nodal metastasis in carcinoma of the rectum and rectosigmoid and found that, of a total of 507 cases studied, 239 had positive lymph nodes. In only eight of these were nodes involved below the lesion, and seven of the eight were within 2 cm. of the lesion. In a study of 100 of their far advanced cases of carcinoma of the upper rectum, rectosigmoid or lower sigmoid, all had lymph node metastasis, and in thirty-six retrograde nodal involvement was found. In only three of these thirty-six cases were the distal nodes not adjacent to the local lesion; one was 2 to 3 cm. below, one 3 to 4 cm., and one 6 to 7 cm. below. The conclusion of Glover and Waugh and of other investigators was that retrograde involvement takes place only when upward lymphatic extension is blocked by carcinomatous nodes. In some cases selected by experts there is justification in removing a carcinoma of the rectum with preservation of the sphincters, but it has been properly emphasized that the lower line of excision should include not only the bowel, but also all surrounding areolar and gland-bearing tissue for at least 5 cm. below the gross edge of the carcinoma.

While there is this revived tendency to try to save the anal sphincteric function by resection of the lesion and end-to-end anastomosis of the colon to the low rectum, many surgeons still prefer the combined abdominoperineal resection for all carcinomas of the rectum.

Surgical Considerations

HERNIA. Within the pelvis a hernia may occur through any one of the normal exits for vessels and nerves, or through an abnormal aperture in the diaphragmatic floor of the pelvic cavity (Fig. 579). Such herniation may be sciatic, obturator or perineal in location.

RECTAL EXAMINATION. Rectal examination may be made instrumentally or digitally. The patient may be examined in the knee-chest, exaggerated lithotomy, lateral prone or squatting position, or hinged almost at right angles over a specially constructed table. Any position with the body dependent causes the intestines to gravitate toward the diaphragm, empties the rectovesical and rectovaginal pouches, relieves downward pressure upon the sigmoid, and permits the rectum to dilate upon the admission of air. A dependent position facilitates the introduction of an examining instrument such as the proctoscope or sigmoidoscope.

The rectum is so located as to render easy, not only digital and endoscopic examination of the organ itself, but also digital examination of several neighboring structures palpable through the walls of the rectum. A brief consideration of these relationships may enable the examiner to project into his mind's eye what he should feel normally, and thus better fit him to evaluate physical findings when a condition of disease is present.

In the male, anterior to the rectum lie the prostate gland, the seminal vesicles and ducts and the urinary bladder (Fig. 580, *a*). The prostate gland is usually felt easily. The seminal vesicles, on the contrary, are not readily felt by palpation unless they are considerably

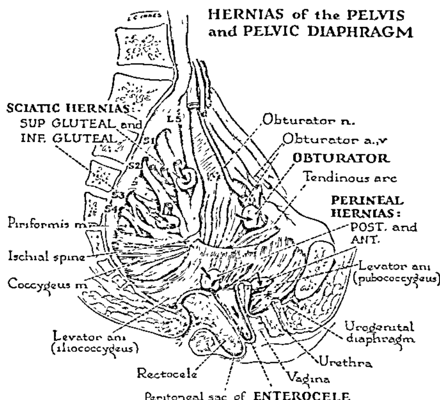


Fig. 579. TYPES OF PELVIC HERNIA, SHOWN IN A VIEW OF THE LEFT HALF OF THE PELVIS.

The viscera have been removed except at their pelvic or perineal termination; the fascial covering of the parietal and diaphragmatic musculature has been dissected away, as have also the retroperitoneal connective tissue and the peritoneum—except where this serous layer forms peritoneal sacs. A sciatic hernia leaves the pelvis through either the suprapiriform or infrapiriform recess of the greater sciatic (ischiadic) foramen, each in close relation to the anterior rami of the sacral nerves and in company with gluteal blood vessels. An obturator hernia would point outward through the small canal in the obturator membrane, following the course of vessels of the same name toward the medial aspect of the thigh. Perineal hernias are protrusions through weakened portions of the musculoaponeurotic fibers, either the pubococcygeal or iliococcygeal portion of the levator ani. Rectocele and cystocele (at arrow marked by *) also illustrated, are not true hernias. (From McVay in Davis: Christopher's Textbook of Surgery.)

distended; they have been graphically described as small, sausage-like structures which extend superiorly and laterally from the base of the prostate as would the ears of a rabbit. In the female the vagina and the uterus lie anterior to the rectum; anterolaterally are situated the uterine adnexa. The rectum thus offers another approach, in addition to the vaginal canal, in the performance of bimanual pelvic examination. Perhaps the most common obstetric use of these relationships is the practice of observing the progress of cervical effacement and dilatation during the first stage of labor by means of repeated rectal, rather than vaginal, examinations.

Just as the rectum provides a means of digital exploration of neighboring structures, so does the vagina in the female allow an approach to certain rectal conditions. In tubular strictures of the rectum, with marked narrowing of the lumen, digital vaginal examination may allow determination of the proximal extent of the stenosis. In the management of fecal impaction in the female, after digital morcellation of the fecal mass has been accomplished, the rectum can be "stripped" from above downward, using the vaginal approach, thus aiding expulsion of the fecal contents. For this reason the problem of fecal impaction can be dealt with much more easily in the female than in the male.

Extrarectal masses in the cul-de-sac in either sex can be felt rectally. The cul-de-sac may be the site of metastases (so-called drop metastases) from growths which involve the pancreas, the gallbladder, the ascending colon, the breast and especially the stomach. Pursuing this relationship still further, it should be pointed out that the anterior wall of the upper half of the rectum provides the proper site for the establishment of drainage per rectum of a collection of purulent material in the cul-de-sac in either sex. The surgeon may prefer, in the female patient, to drain the cul-de-sac vaginally through the posterior fornix. In inflammatory disease of a low-lying appendix it may be possible to determine, on careful rectal examination, the presence of a tender, inflammatory mass high on the right side of the pelvic cavity. This maneuver may be of special value as an aid to the diagnosis of appendicitis in children.

Lateral to the rectum, in each half of the pelvis, are situated the potential pelvirectal space, the pelvic diaphragm, the sacrotuberous and sacrospinous ligaments, the spine of the ischium, the sacral plexus of nerves and the piriformis muscle. As a consequence, a collection of pus in the pelvirectal space will cause encroachment on the lumen of the rectum. The ischial spine is most readily identifiable (Fig. 580, *b*). The examiner should remember, in attempting to palpate the structures that constitute the lateral pelvic wall or lie adjacent to it, that he is feeling those structures through the rectal wall and through the pelvic diaphragm. The ischial spine serves to guide the examining finger to the region of the greater sciatic foramen, which transmits the following important structures: piriformis muscle, superior and inferior gluteal vessels and nerves, internal pudendal vessels and pudendal nerve, sciatic and posterior femoral cutaneous nerves, and nerves to the quadratus femoris and to the obturator internus. In the region of the ischial spine there may be elicited, on digital palpation, exquisite tenderness and pain which follow the distribution of the sciatic (ischiadic) nerve. The significance of this finding with regard to certain forms of sciatica and to the so-called piriform muscle syndrome is still a moot question. The use of the ischial spines to denote station zero in the progress of labor is, of course, well known.

Posterior to the rectum are situated the potential retrorectal space, the sacrum and the coccyx (Fig. 580, *c*). An inflammatory process in the retrorectal space, or any other presacral tumor of sufficient size situated therein, will cause encroachment on the rectal lumen posteriorly. An inpushing of the wall, produced by any such lesion, is easily discernible in the course of careful digital exploration per rectum.

Other valuable information about the interior of the rectum and the structures adjacent to it is obtained by digital examination (Fig. 580). For example, 90 per cent of all carcinomas of the rectum and rectosigmoid can be felt with the examining finger. On passing the well lubricated index finger through the anal orifice, the grasp of the external sphincter is felt. The finger may be advanced upward and forward about 4 cm., where it slips past the internal sphincter and enters the rectal ampulla. The definite constriction at the upper level of the anal canal is caused by the attachment of the rectum to the levator muscles. If the anal orifice is constricted tightly, anal fis-

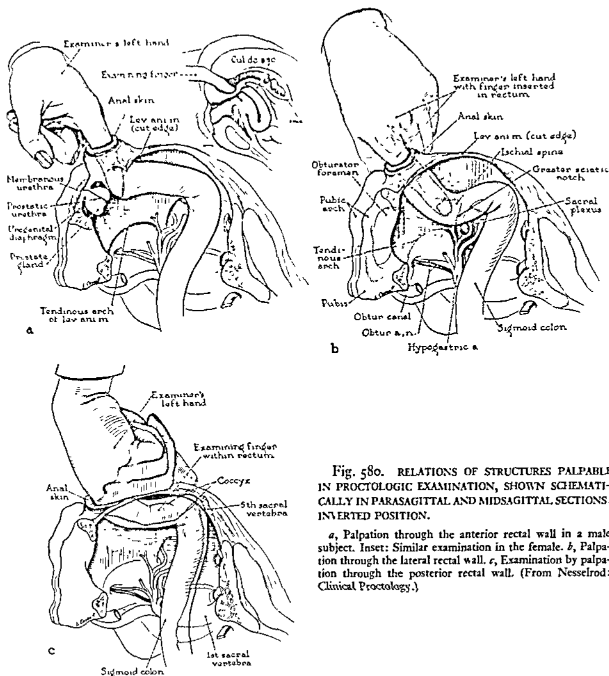


Fig. 580. RELATIONS OF STRUCTURES PALPABLE IN PROCTOLOGIC EXAMINATION, SHOWN SCHEMATICALLY IN PARASAGITTAL AND MIDSAGITTAL SECTIONS; INVERTED POSITION.

a, Palpation through the anterior rectal wall in a male subject. Inset: Similar examination in the female. *b*, Palpation through the lateral rectal wall. *c*, Examination by palpation through the posterior rectal wall. (From Nesselrod: Clinical Proctology.)

sure (p. 697) should be suspected, and further examination should be conducted under anesthesia. If the patient is made to strain, that part of the bowel lying just out of reach of the examining finger can be "threaded" on the finger. A squatting position facilitates digital examination in rectal prolapse and hemorrhoids.

Within the ampulla the examining finger should be directed backward to the hollow of the sacrum. At this stage the middle rectal valve may be felt as an inwardly projecting fold. This valve commonly is the cause of difficulty in passing a rectal tube. The finger, on palpating from side to side, readily explores the anterior aspect of the coccyx and the lower part of the sacrum, upon which the rectum moves with great freedom. The mesial wall of the pelvis may be examined; posterolaterally, enlarged hypogastric lymph nodes can be made out. Anteriorly, through the lowest part of the wall of the rectal ampulla, enlarged bulbo-

distended; they have been graphically described as small, sausage-like structures which extend superiorly and laterally from the base of the prostate as would the ears of a rabbit. In the female the vagina and the uterus lie anterior to the rectum; anterolaterally are situated the uterine adnexa. The rectum thus offers another approach, in addition to the vaginal canal, in the performance of bimanual pelvic examination. Perhaps the most common obstetric use of these relationships is the practice of observing the progress of cervical effacement and dilatation during the first stage of labor by means of repeated rectal, rather than vaginal, examinations.

Just as the rectum provides a means of digital exploration of neighboring structures, so does the vagina in the female allow an approach to certain rectal conditions. In tubular strictures of the rectum, with marked narrowing of the lumen, digital vaginal examination may allow determination of the proximal extent of the stenosis. In the management of fecal impaction in the female, after digital morcellation of the fecal mass has been accomplished, the rectum can be "stripped" from above downward, using the vaginal approach, thus aiding expulsion of the fecal contents. For this reason the problem of fecal impaction can be dealt with much more easily in the female than in the male.

Extrarectal masses in the cul-de-sac in either sex can be felt rectally. The cul-de-sac may be the site of metastases (so-called drop metastases) from growths which involve the pancreas, the gallbladder, the ascending colon, the breast and especially the stomach. Pursuing this relationship still further, it should be pointed out that the anterior wall of the upper half of the rectum provides the proper site for the establishment of drainage per rectum of a collection of purulent material in the cul-de-sac in either sex. The surgeon may prefer, in the female patient, to drain the cul-de-sac vaginally through the posterior fornix. In inflammatory disease of a low-lying appendix it may be possible to determine, on careful rectal examination, the presence of a tender, inflammatory mass high on the right side of the pelvic cavity. This maneuver may be of special value as an aid to the diagnosis of appendicitis in children.

Lateral to the rectum, in each half of the pelvis, are situated the potential pelvirectal space, the pelvic diaphragm, the sacrotuberous and sacrospinous ligaments, the spine of the ischium, the sacral plexus of nerves and the *piriformis muscle*. As a consequence, a collection of pus in the pelvirectal space will cause encroachment on the lumen of the rectum. The ischial spine is most readily identifiable (Fig. 580, *b*). The examiner should remember, in attempting to palpate the structures that constitute the lateral pelvic wall or lie adjacent to it, that he is feeling those structures through the rectal wall and through the pelvic diaphragm. The ischial spine serves to guide the examining finger to the region of the greater sciatic foramen, which transmits the following important structures: piriformis muscle, superior and inferior gluteal vessels and nerves, internal pudendal vessels and pudendal nerve, sciatic and posterior femoral cutaneous nerves, and nerves to the quadratus femoris and to the obturator internus. In the region of the ischial spine there may be elicited, on digital palpation, exquisite tenderness and pain which follow the distribution of the sciatic (ischiadic) nerve. The significance of this finding with regard to certain forms of sciatica and to the so-called piriform muscle syndrome is still a moot question. The use of the ischial spines to denote station zero in the progress of labor is, of course, well known.

Posterior to the rectum are situated the potential retrorectal space, the sacrum and the coccyx (Fig. 580, *c*). An inflammatory process in the retrorectal space, or any other presacral tumor of sufficient size situated therein, will cause encroachment on the rectal lumen posteriorly. An inpushing of the wall, produced by any such lesion, is easily discernible in the course of careful digital exploration per rectum.

Other valuable information about the interior of the rectum and the structures adjacent to it is obtained by digital examination (Fig. 580). For example, 90 per cent of all carcinomas of the rectum and rectosigmoid can be felt with the examining finger. On passing the well lubricated index finger through the anal orifice, the grasp of the external sphincter is felt. The finger may be advanced upward and forward about 4 cm., where it slips past the internal sphincter and enters the rectal ampulla. The definite constriction at the upper level of the anal canal is caused by the attachment of the rectum to the levator muscles. If the anal orifice is constricted tightly, anal fis-

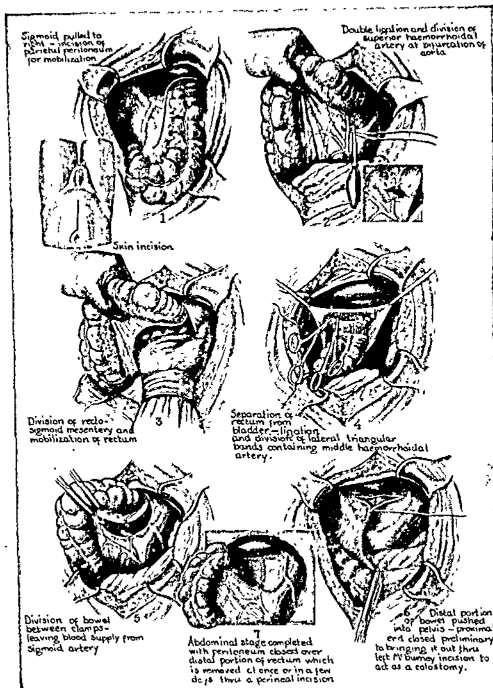


Fig. 581. STEPS IN THE ABDOMINAL PORTION OF THE COMBINED ABDOMINOPERINEAL RESECTION OF THE RECTUM FOR CARCINOMA.

Ligation of the superior hemorrhoidal vessels (2) should be at their highest point, at least 5 cm. above the promontory of the sacrum, in order to remove as many lymph nodes as possible. Sigmoidal arteries may even be divided up to the left colic in the effort to excise nodes along the upward path of lymphatic extension. In the pelvis the rectum and all gland-bearing fatty areolar tissue should be removed as widely as possible in all directions. Extension to adjacent viscera may call for removal of part or all of the pelvic viscera. (Modified from Lewis' Surgery.)

urethral glands (of Cowper) can be felt. About 4 cm. from the anus the apex of the prostate is palpated; above it the posterior surface of the gland is outlined readily because of its firm consistency and regular contour. Above the prostate enlarged seminal vesicles are felt as nodular projections. Between the seminal vesicles the finger is in contact with the interampullary area of the base of the bladder (p. 610). The pouch of Douglas is reached higher up, and inflammatory masses or carcinomatous peritoneal implants may be felt.

In rectal examination in the female the finger contacts the vagina and, above it, the cervix (Fig. 580, *inset*). The cervix, because of its proximity to the rectum and its firm consistency, has been mistaken for a rectal tumor. Bimanual examination, which is examination with one or two fingers in the rectum and the other hand applied to the abdomen, is a valuable adjunct to the diagnosis of the position of the uterus, ovaries and tubes.

A *sigmoidoscopic examination* is the most valuable method of looking into the lumen of the rectum and sigmoid. With the patient in a knee-chest or inverted position on a special table, the sigmoidoscope is passed carefully through the anal canal. The obturator is then removed, and the light is applied. If necessary, a small amount of air is injected to balloon out the rectum, after which, under direct vision, the instrument is carefully passed forward while inspecting the rectal mucosa, the valves of Houston, the rectosigmoid junction and the sigmoid. On removing the sigmoidoscope, the mucosa is again inspected and the anal canal visualized. About 25 cm. of the lower bowel may be thus observed for abnormalities. Small carcinomas of the rectum can be seen which would be overlooked by a barium enema x-ray examination. *Examination of the colon is incomplete without a sigmoidoscopic study.* Failure to make a proper digital and sigmoidoscopic examination accounts for the fact that 20 to 25 per cent of carcinomas of the rectum, rectosigmoid and low sigmoid have been erroneously treated as some other condition of the rectum in the six to eight months prior to the discovery of the tumor.

Combined Abdominoperineal Operation (Miles). This operation has had the greatest general acceptance for removal of a malignancy of the rectum and rectosigmoid. Among good surgeons the hospital mortality rate is about 5 per cent, which is exceedingly low, considering the various other diseases with which these elderly patients are commonly afflicted. The five-year survival rate is about 55 per cent. The approach affords an opportunity for exploring the mass, determining the presence of metastases to the liver, and also for ascertaining whether there is any local and contiguous lymphatic involvement.

With experience the abdominal portion of the resection is relatively easy to carry out (Fig. 581), and the permanent single-barrelled colostomy is brought out through the upper part of the main incision or through a left lower quadrant stab wound. The abdominal wound is closed, the patient is then placed in an exaggerated lithotomy position or lateral Sims' position, and the perineal phase excises the anus and low rectum as widely as possible and removes the whole specimen (Fig. 582).

Complete Excision of Pelvic Viscera. With the knowledge that carcinomas may extend considerably at their local site, yet not metastasize distally for a long time, some surgeons are experimenting with tremendous resections to give the patient the only chance of cure (Fig. 583).

Anterior Resection of the Rectosigmoid and Rectum. This procedure (Figs. 584, 585) for removing malignancies as low down as 10 cm. from the dentate anal line and saving the anal sphincters developed as a result of four factors: *First,* the downward spread of rectal carcinoma to lymph nodes more than 2 cm. below the primary lesion rarely occurs, and then only when proximal nodes are well blocked by malignancy. In such cases it is unlikely that any surgical procedure will be radical enough to eliminate the local lesion, and distant metastases have usually occurred. In doing the anterior resection, bowel wall and all surrounding fatty areolar tissues are removed for 5 cm. below the lower gross edge of the malignancy. *Secondly,* the rectal stump can survive with blood supplied by the inferior hemorrhoidal arteries alone. *Thirdly,* Sudeck's so-called critical point of blood supply to the sigmoid does not exist clinically, so that proximal segments of the upper sigmoid, descending or even transverse colon (Figs. 522, 524) can be developed with good bleeding vessels at the end, and capable of being brought down for anastomosis to the rectal stump. *Fourthly,* the small rectal stump, occasionally no more than

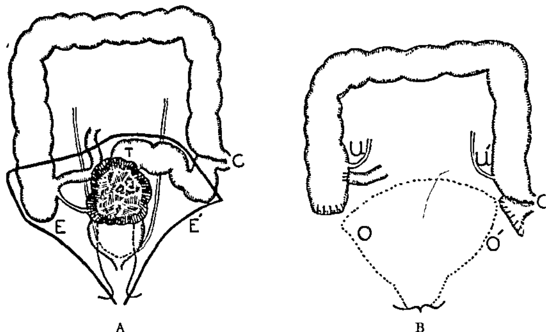


Fig. 583. COMPLETE EXCISION OF PELVIC VISCERA FOR CARCINOMA OF SIGMOID WITH EXTENSIVE LOCAL INVASION.

One year previously the patient had had a left lower quadrant double-barrelled colostomy (*c*) for an "inoperable" carcinoma of the sigmoid with attachment to the bladder. *A*, Condition at second operation: *T*, primary carcinoma in the sigmoid with invasion to the dome of the urinary bladder, tip of the appendix and loop of ileum. Lines *E-E'* indicate areas of excision. The surgical specimen was composed of the sigmoid colon, rectum, anus, urinary bladder, lower ureters, prostate, cecum, appendix and a portion of the proximal ileum. *B*, Postoperative condition: low ileum and right ureter anastomosed to the ascending colon; left ureter anastomosed to the descending colon; "wet" colostomy at *c*.

Follow-up report 14 months later: the patient had gained 25 pounds in weight and had returned to his usual occupation. He wore a colostomy bag glued to the skin. (From Brunschwig: Ann. Surg., 129: 499-504, 1949.)

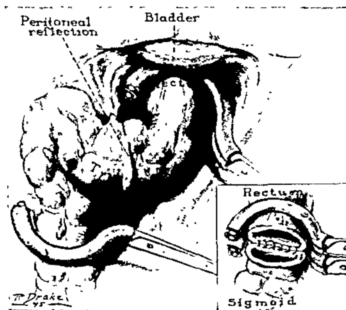


Fig. 584. ANTERIOR RESECTION FOR CARCINOMA OF THE RECTUM.

Note how far up the peritoneal reflection and tumor can be raised after the rectum has been freed. Anastomosis is of the "open type." (From Dixon: Ann. Surg., 128: 425-42, 1948.)

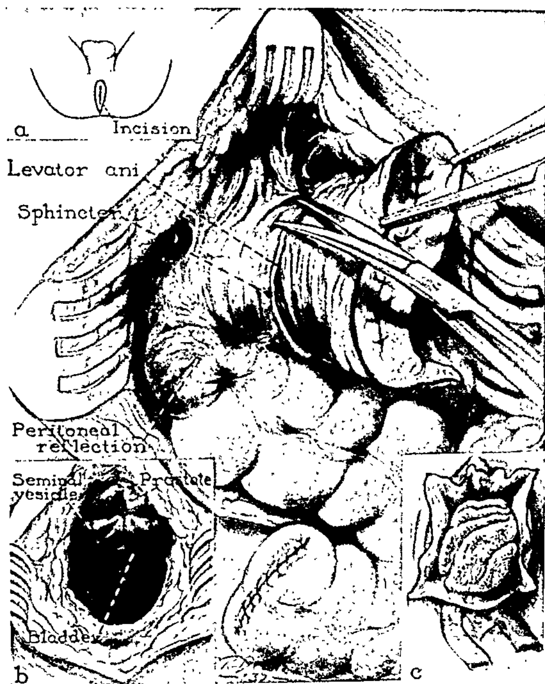


Fig. 582. PERINEAL PHASE OF ABDOMINOPERINEAL RESECTION OF THE RECTUM FOR CARCINOMA.

An elliptical incision surrounds the sutured anus and excises it to the levator ani muscles. These are divided widely at their origin with the adjacent soft parts in order to remove possible lateral lymphatic and venous spread. The pelvis is entered in the hollow of the sacrum, and the sutured sigmoid stump and rectum are withdrawn. The lateral ligaments are divided and the rectum excised anteriorly from (*b*) the bladder, seminal vesicles and prostate in the male. In the female this line of excision is from the vagina. If involved with carcinoma, portions or all of these structures may be removed (Fig. 583). Pack and drain inserted (*c*) in the large pelvic wound. Some surgeons use only a soft rubber drain. Most of the wound is closed loosely about this drain. (From Cole: Operative Technic—General Surgery, New York, Appleton-Century-Crofts.)

4 to 5 cm. long, provides functional impulses sufficient to permit normal evacuation through anal sphincters as controllable as they were before the resection.

In one series of 272 cases of anterior resection for carcinoma of the upper part of the rectum and lower sigmoid, the operative mortality rate was 2.6 per cent, and the five-year survival rate was 67.7 per cent.*

* Wangensteen: Primary Resection (Closed Anastomosis) of Rectal Ampulla for Malignancy with Preservation of Sphincteric Function. Surg., Gynec. & Obst., 81: 1-24, 1945; Dixon: Anterior Resection for Malignant Lesions of the Upper Part of the Rectum and Lower Part of the Sigmoid. Ann. Surg., 128: 425-42, 1948

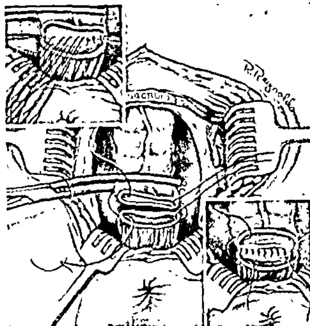


Fig. 587. SIGMOID-TO-RECTUM ANASTOMOSIS DONE THROUGH THE PERINEAL INCISION AS PART OF ABDOMINOPERINEAL RESECTION FOR CARCINOMA OF THE RECTUM WITH PRESERVATION OF THE SPHINCTERS.

This procedure is suitable in place of anterior resections for small, freely movable carcinomas from 8 to 10 cm. above the mucocutaneous line. The abdominal phase is the same as for the Miles operation (Fig. 581). Through the perineal wound the *rectum, levator ani muscles and surrounding gland-bearing tissue* can be dissected and excised 5 cm. *below the gross edge of the* tumor. The low anastomosis is easier than by the anterior approach. Usually a temporary left transverse colostomy is done to divert the fecal stream for 3 to 4 weeks. (From Best: Surg., Gynec. & Obst., *86*: 98–106, 1948.)

Frequently a temporary transverse colostomy is done at the time of the anterior resection in order to divert the fecal stream from the line of anastomosis for three to four weeks.

ABDOMINOPERINEAL RESECTION OF THE RECTUM WITH PRESERVATION OF THE SPHINCTERS.* Another method of excising a tumor of the low sigmoid or upper rectum is the abdominoperineal *proctosigmoidectomy* or *pull-through operation.* The abdominal phase of this procedure is essentially the same as that for the Miles abdominoperineal resection (Fig. 581). The perineal portion is carried out inside the anal sphincters, which are dissected away and widely retracted from the anus (Fig. 586). The surgeon then proceeds upward to meet the bowel freed during the abdominal phase. The rectum and sigmoid with the tumor are then pulled through the anal canal area and cut off several centimeters outside the anal sphincters. The sphincters then heal about the sigmoid, as a closing muscle.

The chief objections to the pull-through operation are that the low dissection of the perirectal node-bearing tissue is inadequate, and sphincter function leaves something to be desired, roughly 60 per cent having fair control and 40 per cent requiring the wearing of a

* Bacon: Evolution of Sphincter Muscle Preservation and Re-establishing of Continuity in the Operative Treatment of Rectal and Sigmoidal Cancer. Surg., Gynec. & Obst., 81: 113–27, 1945; Murray: Resection of the Rectum with Reconstruction of the Canal through the Perineal Approach. Surg., Gynec. & Obst., 82: 283–9, 1946; Best: Selection of Operative Procedure to Avoid Colostomy in Carcinoma of Rectum and Rectosigmoid. Surg., Gynec. & Obst., 86: 98–116, 1948; Maddock: Carcinoma of Rectum. Treatment with Preservation of the Sphincters. Wisconsin M. J., 48: 124–32, 1949; Gaston: Fecal Incontinence Following Resection of Various Portions of the Rectum with Preservation of the Anal Sphincters. Surg., Gynec. & Obst., 87: 669–78, 1948.

Fig. 586. PERINEAL PHASE OF PROCTOSIGMOIDECTOMY OR PULL-THROUGH OPERATION.

The abdominal part of this operation is essentially the same as for the Miles operation (Fig. 581). This illustration shows the anus closed by sutures. The sphincter muscles have been dissected from the rectal wall and *retracted laterally, the levator* ani muscles divided, and the bowel freed posteriorly and anteriorly from the prostate and seminal vesicles. The rectum and sigmoid with the tumor will then be pulled through the anus and cut off. The anal sphincters will then contract about and heal to the sigmoid, which will *retract to a point just within the dentate line.* (*From Bacon: Surg., Gynec. & Obst.,* 81: 113–27, 1945)

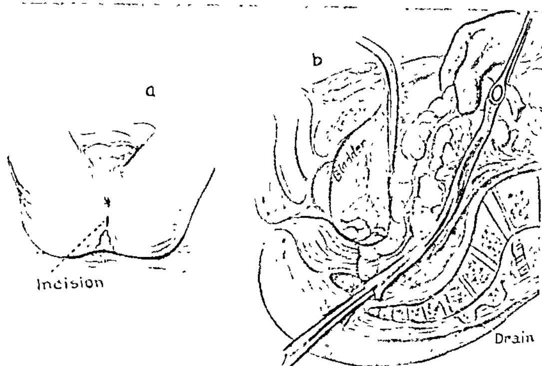


Fig. 585. LOW PELVIC LEVEL AT WHICH ANASTOMOSIS CAN BE DONE IN ANTERIOR RESECTION OF THE RECTUM FOR CARCINOMA.

a, Perineal incision just anterior to the coccyx through which a soft rubber drain is drawn from below. *b*, Some surgeons bring the drain out through the lower end of the abdominal wound. A "closed type" of anastomosis can be done. (From Wangensteen: Surg., Gynec. & Obst., 81: 1–24, 1945.)

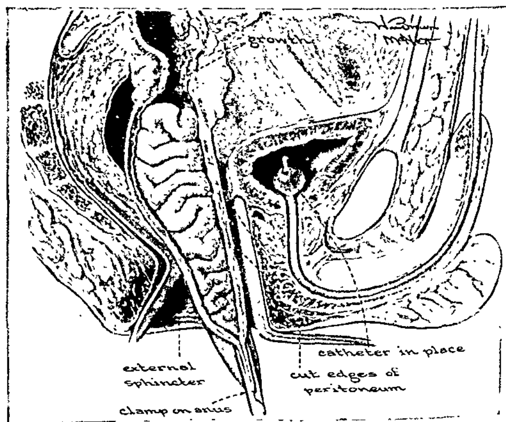


Fig. 586.

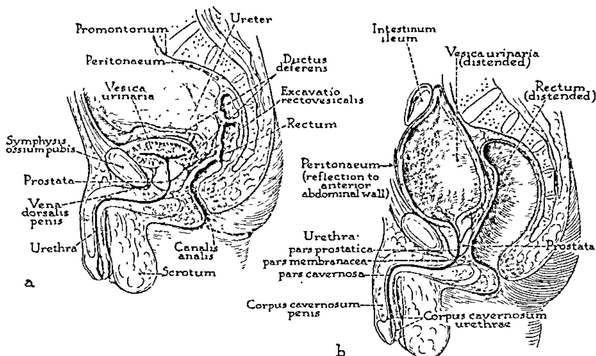


Fig. 588. URINARY BLADDER (VESICA URINARIA), IN THE EMPTY AND THE DISTENDED STATES. MEDIAN SECTIONS OF ADULT MALE SUBJECTS. (REDRAWN FROM CUNNINGHAM'S TEXTBOOK.)

a, The contracted bladder is a thick-walled organ; it is situated in the lesser pelvis with the superior surface on a plane with the corresponding surface of the body of the pubis. The empty bladder, as seen in section, is bluntly wedge-shaped. The narrow vertex is directed anteriorly; the broader fundus faces posteriorly.

b, When full, the bladder, projecting upward into the peritoneal cavity, may ascend to a level cranial to that of the promontory formed by the union of the fifth lumbar vertebra with the sacrum; in form it becomes egg-shaped. During the course of the ascent the line of reflection of the peritoneum from the superior surface of the organ to the anterior abdominal wall is progressively lifted to reach, or even to pass, the level of the umbilicus. As a result, the bladder is in contact for some distance with the abdominal musculature (separated therefrom only by the stratum of subserous connective tissue.)

The space is bounded anteriorly by the posterior sheath of the rectus muscle and the posterior surface of the pubes. An effusion here may extend rapidly into the extraperitoneal tissue of the abdominal wall and pelvis. The continuity of the extraperitoneal areas about the inguinal and femoral hernial regions explains the presence of a segment of bladder in hernias. Inflammatory involvement of the space follows vesical infection, urinary extravasation in extraperitoneal rupture of the bladder, and infection which gravitates into the pelvic part of the space from urinary extravasation after suprapubic cystotomy. The guiding principle in treatment of these infections is free evacuation and adequate drainage.

Fixation of the Bladder. The bladder is anchored securely only at its base, where it is fixed by continuity with the prostate and urethra, which, in turn, are bound to the urogenital diaphragm (triangular ligament) (p. 692). The neck of the bladder is fixed also by the pubovesical and puboprostatic ligaments, which bind it to the symphysis. These ligaments are bundles of fibers derived from the visceral layer of pelvic fascia. The median umbilical ligament, containing the urachus, maintains the bladder in position anteriorly and superiorly (Fig. 368, p. 383). The lateral umbilical ligaments, containing the atrophied supravesical portions of the fetal umbilical arteries, stabilize the bladder. The lateral and median umbilical ligaments are bladder supports only in the sense that they act as guides in maintaining the bladder against the anterior abdominal wall when the bladder fills and rises out of the pelvis. Posteriorly, the bladder is reinforced by the rectovesical fascia (of Denonvilliers) (Fig. 569). The viscus lies within the visceral layer of pelvic fascia. After difficult deliveries the bladder may be loosened from its attachment to the pelvic floor and may prolapse into the perineum, appearing at the vulva as a cystocele.

pad. Gaston reports that resection of all the rectum with anastomosis of the sigmoid to the anus at the level of the mucocutaneous line results in loss of sphincteric continence, and the recto-anal reflex of lessened sphincter tone in preparation for evacuation of feces could not be elicited. With 7 cm. of rectum remaining, these reflexes were normal; with 1 to 2 cm. the test was equivocal. As might be expected, at least a few centimeters of rectum are needed for the preservation of sphincteric and recto-anal reflexes.

A few surgeons in selected cases of small, freely movable carcinomas of the rectum within 8 to 10 cm. of the anal sphincters, where anterior resection may be difficult and a good margin of rectum and perirectal tissue below the tumor are hard to remove, do an abdominoperineal resection of the rectal malignancy with the low sigmoidorectal anastomosis through the perineal wound (Fig. 587). The abdominal phase is the same as that described for the Miles operation. The perineal portion is performed through a posterior midline incision with removal of the coccyx and a small part of the sacrum. Through this wound the pelvis is entered, and the previously freed rectum and sigmoid with the tumor are withdrawn. The lower part of the rectal dissection is then done. The levator ani muscles are excised widely at their origin, and perirectal gland-bearing tissue is dissected with the rectum as in the Miles procedure. The bowel is transected 5 cm. below the tumor edge, and the anastomosis is much more easily done 3 to 5 cm. above the sphincters than by the method of anterior resection. With this amount of rectum remaining, sphincter control and defecation sense have been normal.

Urinary Bladder

Location and Shape. The urinary bladder is located anteriorly in the pelvis, immediately posterior to the pubes. When the bladder is empty and contracted, it is wedged in the forward part of the pelvis; its walls lie in contact, and its cavity is reduced to a mere slit (Fig. 588, *a*). Toward the pelvic cavity the upper or posterosuperior surface of the bladder is rounded and is covered by the peritoneum of the anterior wall of the pelvis. This surface is triangular; its apex, which is directed forward, lies behind the symphysis and is connected with the urachus; the lateral or basal angles correspond to the points at which the ureters reach the bladder. The interval between these angles, indicated by a ridge, is the posterior or basal margin of the bladder.

When the bladder is distended, it undergoes marked alterations. The posterior and lateral boundaries become rounded, and the viscus assumes an oval outline (Fig. 588, *b*). The upper or posterosuperior wall of the bladder rises and gradually encroaches upon the pelvic cavity. The lateral surfaces are increased; consequently more of the bladder comes into relation with the pelvic organs. The line of peritoneal reflection rises to a much higher level, and the bladder floor bulges downward. As the bladder expands, it mounts gradually over the pubes. The pubovesical reflection of peritoneum rises a variable extent, so that the bladder wall lies directly against the abdominal wall except for some intervening fatty tissue. Even when the viscus is distended greatly, the peritoneal reflection anteriorly may rise but slightly. Occasionally the peritoneum is more than usually adherent behind the symphysis, and elevation of the pubovesical reflection is prevented. Advantage is taken of the rising of the pubovesical peritoneum in aspirating the overdistended bladder suprapubically, and in the operation of suprapubic cystotomy. The same relationship may be obtained by distending the viscus artificially.

The bladder occupies a higher position in the very young child than in the adult because of the smaller relative size of the pelvis and the greater relative size of the bladder. The neck of the bladder lies almost on a level with the upper margin of the symphysis, and most of the bladder lies in the abdomen. For this reason the bladder should be evacuated before making any incision in the lower part of the anterior abdominal wall, especially in inguinal hernioplasty (p. 392).

Perivesical Spaces. The bladder, like the rectum, is encompassed partly by extraperitoneal, areolar, connective tissue spaces, an arrangement which accommodates the distention demanded of the viscus. Of the tissue spaces, the prevesical area is clinically important because of the infections set up in it or propagated to it.

The *prevesical space* (of Retzius) lies partly in the pelvis and partly in the abdomen, and is a division of the extraperitoneal space which extends from the pelvic floor to the umbilicus.

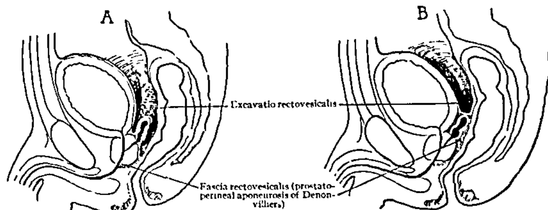


Fig. 590. VARIATIONS IN THE DEPTH OF THE RECTOVESICAL CUL-DE-SAC.

A, The rectovesical cul-de-sac extends below the level of the superior surface of the prostate. *B*, The cul-de-sac does not reach the seminal vesicles; in this instance the rectum is in direct relation with the bladder, seminal vesicles and prostate.

the embryonic pouch approximates and fuses from below upward, so that there is formed a frontally disposed fascia, the rectovesical or prostatoperitoneal fascia (of Denonvilliers) (Fig. 569).

INTERIOR OF THE BLADDER. The appearance of the bladder varies according to the degree of tension on the lining mucosa, which is loosely adherent to the muscle layer through a relatively loose submucosa. In the contracted organ the mucosa is thrown into folds and presents a wrinkled appearance. In the distended organ the mucosa has fewer folds; but even with the fullest distention there remains a corrugated appearance caused by the interlacing subjacent muscle columns (Fig. 589).

In the region of the urethral orifice the mucosa undergoes a striking modification. It is comparatively smooth over a triangular area known as the *trigone* (Fig. 591). The apex of the trigone lies at the *urethral orifice;* the base corresponds to an imaginary line, indicated usually by a well defined elevation, the *interureteric ridge*, which connects the orifices of the ureters. The prominence of the ridge depends upon the elevation of the mucosa over the muscle elements which are raised by the oblique passage of the ureters through the bladder wall. The distance between the orifices measures from 2 to 3 cm. and varies with the size and degree of distention of the viscus. The center of the trigone is depressed toward the urethral orifice, and is the most frequent area of localization of disease of the bladder (pathologic zone). The urethral orifice is not circular, because of a median elevation, the *vesical crest* or *uvula*, in its posterior circumference. The crest consists in a thickening of mucous membrane over a framework of muscle tissue, and is continued through the urethral orifice to the floor of the prostatic urethra. Inflammatory lesions about the urethral orifice are characterized by painful and frequent urination, often accompanied by muscle spasm and urinary retention.

The obliquely placed *ureteral orifices* open upon the mesial extremities of a well defined ureteric fold. They usually are slitlike, but may be oval or round, and their direction is obliquely transverse. The lateral margin of each *orificium ureteris* (Fig. 591) is guarded by a valvelike projection, while the mesial margin lies embedded in the fold.

The interior of the fundus of the bladder, or *retrotrigonal fossa*, is depressed. When the fossa is rendered large and deep by increased intravesical pressure from prostatic hypertrophy, urinary residues accumulate within it, and stagnation occurs. Foreign bodies gravitate to the fossa, and bladder ruptures occur through it.

The mucous membrane of the bladder is located midway in the genitourinary tract and is prone to pathologic changes, of which cystitis is the most common. Cystitis nearly always is transmitted from the kidneys. From the urethra there easily develops a trigonitis, but scarcely ever a cystitis. The generous nerve supply of the region explains the exquisite pain and sensitiveness coincident with infection and edema. Spasmodic contraction of the muscle elements in the vesical and upper urethral walls

RELATIONS OF THE BLADDER. Anteriorly and inferiorly, the bladder is related to the pubic bones, symphysis, retropubic fat, anterior vesical veins, and the vesical portion of the pelvic fascia (Fig. 589). Fragments from a pubic fracture may penetrate the prevesical space and lacerate the bladder. Traumatic separation of the symphysis may cause bladder rupture from the sudden pull exerted on the pubovesical ligaments. The lateral aspect of the bladder is related to the levator ani and obturator internus muscles, the parietal layer of pelvic fascia, and the vesicoprostatic (or vesical) venous plexus (Fig. 589).

In the male the postero-inferior (basal) aspect of the bladder is related to the rectum, but is separated from it by the seminal vesicles, the deferent ducts and their ampullae, and the rectovesical fascia (of Denonvilliers). There is a small interval between the deferent ducts and the inferior reflection of the bladder serosa. This area, the interdeferent triangle (p. 615), increases slightly in size as the bladder becomes distended. For puncture of the bladder by the old-fashioned rectal route, a trocar was passed through this extraperitoneal area. The terminal parts of the ureters lie between the upper rounded extremities of the seminal vesicles and the bladder wall. In the female the bladder is related posteriorly to the shallow uterovesical pouch of peritoneum separating it from the body of the uterus. Below this peritoneal pouch the bladder is in direct relation with the cervix and the anterior vaginal wall. Lateral to the ureter, the bladder is related to the anterior layer of the broad ligament (Fig. 699, p. 741). The bladder has posterosuperior relations with the pelvic colon and loops of small bowel. It is overlaid by the fundus and body of the uterus. The erosion of adhesions between the bladder and small bowel may form an intestinovesical fistula.

RECTOVESICAL FASCIA. The extent to which the prostate and seminal vesicles are covered by peritoneum depends upon the depth of the rectovesical pouch (Fig. 590). As a developmental anomaly, this pouch occasionally may reach to within 1 or 2 cm. of the anus or even lower, and may contain intestinal loops which have herniated into the perineum. About the fourth or fifth intrauterine month the cul-de-sac extends to the pelvic floor; in the newborn it reaches to the base of the prostate. The peritoneum of the anterior and posterior walls of

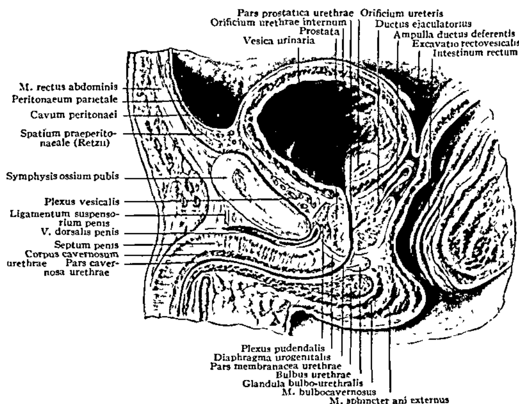


Fig. 589. MIDSAGITTAL SECTION THROUGH THE PELVIS AND PERINEUM WITH THE BLADDER DISTENDED.

The structures in relation to the bladder are shown in detail.

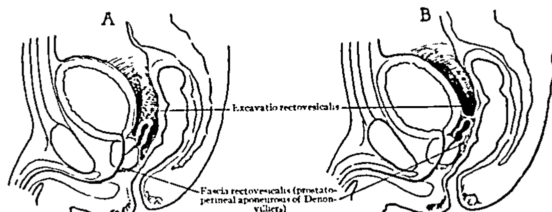


Fig. 590. VARIATIONS IN THE DEPTH OF THE RECTOVESICAL CUL-DE-SAC.

A, The rectovesical cul-de-sac extends below the level of the superior surface of the prostate. *B*, The cul-de-sac does not reach the seminal vesicles; in this instance the rectum is in direct relation with the bladder, seminal vesicles and prostate.

the embryonic pouch approximates and fuses from below upward, so that there is formed a frontally disposed fascia, the rectovesical or prostatoperitoneal fascia (of Denonvilliers) (Fig. 569).

INTERIOR OF THE BLADDER. The appearance of the bladder varies according to the degree of tension on the lining mucosa, which is loosely adherent to the muscle layer through a relatively loose submucosa. In the contracted organ the mucosa is thrown into folds and presents a wrinkled appearance. In the distended organ the mucosa has fewer folds; but even with the fullest distention there remains a corrugated appearance caused by the interlacing subjacent muscle columns (Fig. 589).

In the region of the urethral orifice the mucosa undergoes a striking modification. It is comparatively smooth over a triangular area known as the *trigone* (Fig. 591). The apex of the trigone lies at the *urethral orifice;* the base corresponds to an imaginary line, indicated usually by a well defined elevation, the *interureteric ridge*, which connects the orifices of the ureters. The prominence of the ridge depends upon the elevation of the mucosa over the muscle elements which are raised by the oblique passage of the ureters through the bladder wall. The distance between the orifices measures from 2 to 3 cm. and varies with the size and degree of distention of the viscus. The center of the trigone is depressed toward the urethral orifice, and is the most frequent area of localization of disease of the bladder (pathologic zone). The urethral orifice is not circular, because of a median elevation, the *vesical crest* or *uvula*, in its posterior circumference. The crest consists in a thickening of mucous membrane over a framework of muscle tissue, and is continued through the urethral orifice to the floor of the prostatic urethra. Inflammatory lesions about the urethral orifice are characterized by painful and frequent urination, often accompanied by muscle spasm and urinary retention.

The obliquely placed *ureteral orifices* open upon the mesial extremities of a well defined ureteric fold. They usually are slitlike, but may be oval or round, and their direction is obliquely transverse. The lateral margin of each *orificium ureteris* (Fig. 591) is guarded by a valvelike projection, while the mesial margin lies embedded in the fold.

The interior of the fundus of the bladder, or *retrotrigonal fossa*, is depressed. When the fossa is rendered large and deep by increased intravesical pressure from prostatic hypertrophy, urinary residues accumulate within it, and stagnation occurs. Foreign bodies gravitate to the fossa, and bladder ruptures occur through it.

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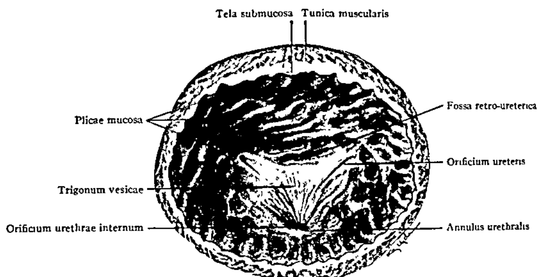


Fig. 591. FUNDUS OF THE BLADDER AND THE TRIGONAL REGION.

causes the colicky type of pain (tenesmus) of cystitis.

VESSELS AND NERVES. The *arterial* supply of the bladder reaches it laterally, anteriorly and posteriorly from the visceral branches of the hypogastric artery or from the hypogastric artery itself (Fig. 571). Small branches from the internal pudendal and obturator arteries supply the anterior portion of the bladder. The superior vesicular arteries, which are the unobliterated portion of the umbilical arteries, supply the superolateral walls. They reach the bladder under the lateral reflection of the pelvic peritoneum. The inferior vesicular arteries from the hypogastric artery share their distribution between the floor of the bladder, the prostate and the prostatic urethra. A vesicular branch from the middle hemorrhoidal artery partially supplies the posterior surface of the bladder and the seminal vesicles. These vessels form a perivesical network, and their rami penetrate the mucosa. Erosion of these vessels explains the hematuria common in bladder disease.

The vesical *veins* are arranged in a plexiform manner throughout the walls. The larger stems are directed to the plexuses in the basal region which, in the male, lie in the groove between the bladder and prostate (vesicoprostatic plexus). Phlebitis of these veins is a grave condition because they propagate infection to the large hypogastric vein.

The *lymphatics* draining the bladder are connected with glands arranged along the ext iliac and hypogastric vessels (Fig.

Surgical Considerations

INJURIES OF THE BLADDER. The infrequency of bladder wounds may be accounted for largely by the well protected position of the viscus within the pelvic cavity. Bladder injury may occur in various ways: the viscus may be lacerated by sharp bony fragments in fractures of the pelvis (Fig. 592); if the bladder is distended considerably, it may rupture from a direct blow over the hypogastrium; it may be injured by penetrating wounds through the hypogastrium; or it may be torn by violence exerted through the rectum and vagina or by trauma to the perineum. Penetrating wounds directed through the greater sciatic or the obturator foramina may penetrate the bladder.

Bladder rupture rarely follows distention alone if the bladder walls are healthy, but it may occur spontaneously through an ulcerated area or through a wall long subjected to pressure from urinary obstruction. In neglected cases of urethral stricture the bladder usually maintains its integrity, and the urethra proximal to the stricture gives way (p. 713). In a bladder rendered immobile by pericystitis or pelvic cellulitis, less force is required to produce rupture. The likelihood of injury from trauma is proportionate to the degree of distention of the bladder and the consequent elevation of the viscus from the protection of the pelvis. Drunkenness predisposes to bladder distention, and a blow, scarcely appreciated by the patient in his stuporous condition, may rupture it. The walls of a distended bladder

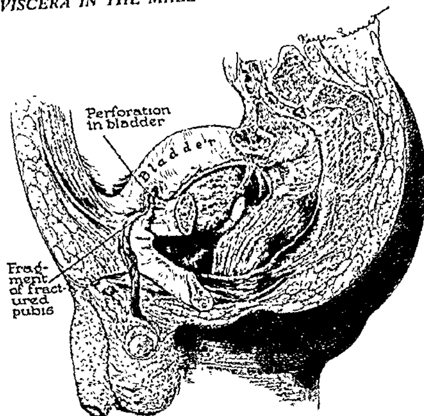


Fig. 592. BLADDER INJURY FROM FRACTURE OF THE PUBIS.

lose their elasticity, and force applied to its contained fluid produces a rupture at the weakest point.

Intraperitoneal rupture occurs in that part of the bladder covered by peritoneum, and *extraperitoneal rupture* in that not covered by peritoneum; when the tear involves only the mucomuscular coats, the lesion is *subperitoneal*, and the urine extravasates beneath the peritoneal covering. The commonest location for rupture is the posterosuperior aspect of the bladder. Rupture involving the anterior surface alone is unusual.

The symptoms of bladder rupture depend largely upon the escape of urine into the surrounding regions, and vary with the location of the lesion. Urine in the abdominal cavity produces the most evident symptoms. If the patient is unable to void, the diagnosis of rupture of the bladder may be made by immediate catheterization (Fig. 594). If catheterization withdraws only a little bloody urine or cannot withdraw all of a measured quantity of fluid instilled, rupture of the bladder is certain. Whether the rupture be intraperitoneal or extraperitoneal, immediate closure must be done by means of a suprapubic cystotomy. Urine may be diverted through a suprapubic cystotomy tube or an indwelling urethral catheter, or both. Roentgenograms of the bladder after intravenous injection of a radiopaque dye which is secreted by the kidney reveal the outlines of the bladder and may reveal a defect in its walls.

ROUTES TO THE BLADDER. The *urethral* or *cystoscopic route* to the bladder is used for diagnostic purposes. The cystoscope has proved an invaluable aid in the diagnosis and treatment of bladder conditions. It makes possible examination of the mucosa, catheterization of the ureters, and removal of small bladder growths, foreign bodies and calculi. Because of the comparative shortness and dilatability of the urethra in the female, cystoscopy in the female is much simpler than in the male.

The *peritoneal approach* is discussed in the section on the perineum (p. 629).

The median hypogastric or *suprapubic route* usually is selected for surgery of the bladder, since it affords excellent access for the removal of calculi and new growths, and for prostatectomy (p. 625). Suprapubic cystotomy frequently is performed for the purpose of draining the bladder. It is the aim of the operation

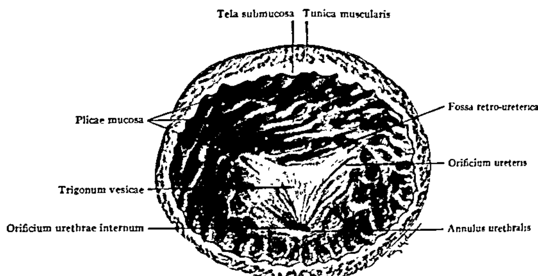


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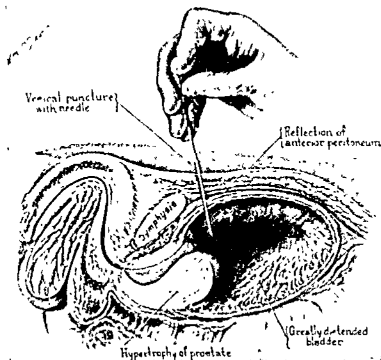


Fig. 595. EMERGENCY SUPRAPUBIC PUNCTURE WITH LONG SPINAL NEEDLE TO RELIEVE ACUTE URINARY OBSTRUCTION.

(From Kerwin: S Clin. North America, 35: 497–515, 1955.)

culty, because the connection of the peritoneum to the bladder is loose. An emergency suprapubic puncture to relieve acute urinary obstruction is a helpful procedure at times (Fig. 595). The bladder may simply be emptied to relieve great distress and the patient promptly conveyed to the hospital for appropriate surgery, or, following along the aspirating needle, a suprapubic trocar and cannula may be inserted, followed by a Foley bag catheter.

Intrapelvic Portion of the Deferent Ducts; Seminal Vesicles; Prostate; Prostatic Urethra

DEFERENT DUCTS. The intrapelvic portion of each deferent duct extends from the abdominal inguinal ring to the base of the prostate (Figs. 596, 597). On leaving the inguinal canal, it descends into the pelvic cavity by crossing the lateral and posterior aspect of the inferior epigastric artery. It then runs downward, backward and mesially, and crosses over the external iliac vessels to reach the lateral walls of the true pelvis. After crossing the ureter it runs beneath the peritoneum to the angle formed by the seminal vesicles. In this angle the two ducts contribute to the formation of the interdeferent triangle. In its terminal part each duct is enclosed within the thickness of the frontally disposed rectovesical fascia (of Denonvilliers), and widens into an *ampulla*. The ampullae converge and unite with the excretory ducts of the seminal vesicles to form the ejaculatory ducts, which traverse the prostate and open on the prostatic urethra.

SEMINAL VESICLES. The seminal vesicles are sacculated membranous reservoirs which are off-shoots from the deferent ducts (Figs. 596, 597). They are invested partially by the peritoneum of the rectovesical pouch, and the terminal parts of the ureters separate them from contact with the bladder wall. The lower, pointed extremity of the vesicle narrows to form the excretory duct and is received into the fissure of the base of the prostate, where it joins the lateral aspect of the ampulla of the corresponding vas. From their communication at the base of the prostate the ejaculatory ducts run forward and downward between its median and lateral lobes and in front of the posterior lobe of the prostate to converge and empty into the prostatic urethra close to the orifice of the prostatic utricle (p. 622).

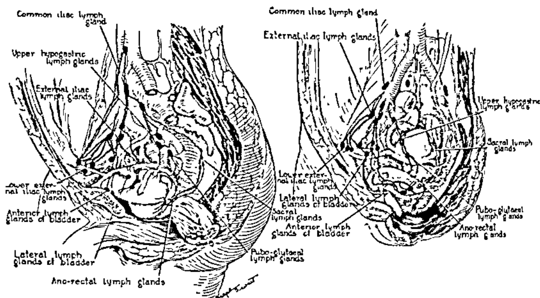


Fig. 593. LYMPHATIC DRAINAGE OF THE MALE AND FEMALE BLADDERS.
(From Hinman.)

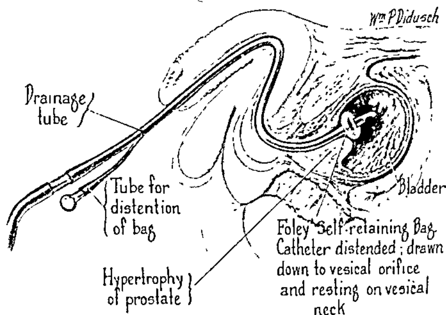


Fig. 594. FOLEY SELF-RETAINING URETHRAL CATHETER WITH INFLATION BAG.
Sectional view showing the inflation bag distended, anchoring the catheter securely in the bladder. (Courtesy of American Cystoscope Makers, Inc.)

to expose the bladder below the line of reflection of the peritoneum from the abdominal wall, so that the peritoneal cavity is not opened. As a preliminary step, it may prove helpful to have the bladder distended with a sterile solution.

Either a vertical median or a transverse incision approximately midway between the symphysis and the umbilicus may be made. The latter is placed high, so as to avoid opening the retropubic space (of Retzius) and the lower portions of the paravesical region. In the average case the incision should terminate just above the junction of the pyramidalis and the rectus muscle. The peritoneal reflection is [illegible] diffi- drawn upward out ol

amined through the rectum. The prostate is traversed from its base to its apex by the first or prostatic part of the urethra. A groove separates the lateral margins of the prostate from the base of the bladder. The ejaculatory ducts traverse downward and forward and empty into the posterior wall of the prostatic urethra.

There is scant periprostatic tissue at the sides of the gland, but abundant tissue anteriorly, consisting largely of the periprostatic venous plexus. This tissue is the seat of periprostatic abscess. Pus from such an abscess, or the extravasated urine after prostatic rupture, tends to invade the extraperitoneal space of the pelvis (p. 587) rather than the perineum.

For the prostate, as for the thyroid (p. 188), there is an intrinsic capsule incorporated with the fibrous elements, and an extrinsic sheath (Fig. 600). The *prostatic capsule* consists of parallel layers of fibromuscular tissue continuous with, and forming part of, the stroma of the organ. The prostatic capsule is of such strength that adenomas of the prostate grow superiorly into the bladder along the line of least resistance. The *prostatic sheath* or *false capsule* is formed anteriorly and laterally by periprostatic connective tissue derived from the pelvic fascia in which the prostatovesical plexus of veins lies. A few veins lie in the loose tissue between the sheath and capsule. Posteriorly, the sheath is formed by the avascular rectovesical fascia of Denonvilliers. This fascia is of fair thickness and acts as an efficient barrier to the reciprocal spread of prostatic or rectal malignant disease. In the enucleation of

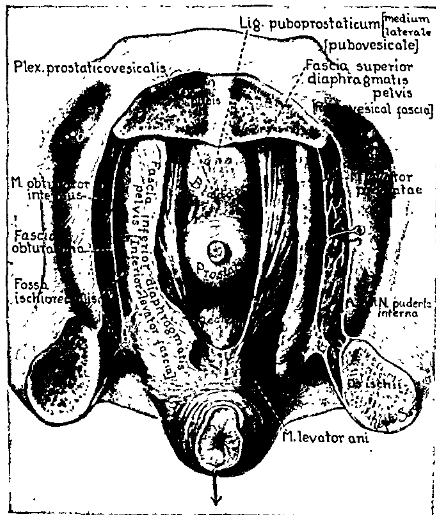


Fig. 598. PERINEAL ASPECT OF THE LEVATOR ANI PORTION OF THE PELVIC DIAPHRAGM.
The ischium or inferior part of the bony pelvis has been cut away; the urogenital diaphragm has been removed to show the interlevator cleft and the intrapelvic structures.

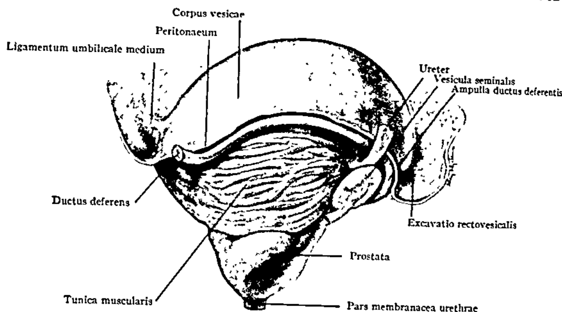


Fig. 596. LATERAL VIEW OF THE BLADDER AND MALE PELVIC GENITALS.

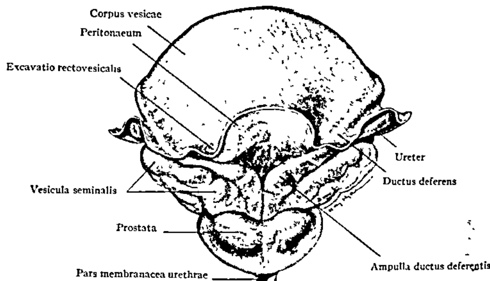


Fig. 597. POSTERIOR VIEW OF THE BLADDER AND MALE PELVIC GENITALS.

Seminal vesiculitis usually is secondary to infection elsewhere in the genitourinary tract. Gonococcal vesiculitis sometimes succeeds prostatitis and may terminate in abscess formation. The abscess may discharge its contents into the rectum or bladder, or even into the pelvic peritoneal cavity, although this usually is prevented by the adhesions resulting from a localized peritonitis. The infection may extend downward through the pelvic diaphragm to the perineal region by a mechanism similar to that for the spread of prostatic abscess (p. 623).

Tuberculosis of the epididymis (p. 719) is thought to be secondary to tuberculous vesiculitis, extension being along the vas. The infection may originate in the kidney. Rectal examination reveals the extent of the swelling of the seminal vesicles. The seminal vesicles are approached through an incision anterior to the anus, similar to incision for perineal prostatectomy.

PROSTATE. The prostate is a solid musculoglandular body of firm consistency, comparable in size and shape to a chestnut (Figs. 596 to 601). Its apex is directed downward and rests upon the superior fascia of the urogenital diaphragm (p. 693). The posterior surface of the organ is in contact with the rectum through the intermedium of the rectovesical fascia and can be palpated readily on rectal examination. The lateral surfaces lie against the mesial borders of the levators and also can be ex-

The glands forming the *median* or *prespermatic lobe* originate on the posterior surface of the floor of the urethra just superior to the urethral openings of the ejaculatory ducts. The lobe, therefore, is posturethral and prespermatic. The glands grow backward and upward toward the bladder in such a fashion that median lobe hypertrophy causes urinary obstruction by pushing the urethra forward at the apex of the trigone. When this lobe hypertrophies upward, it lifts the bladder mucosa which is behind the urinary orifice and dilates and destroys the internal sphincter; sometimes it gives rise to a large, irregular mass which seriously deforms the bladder orifice, hinders spontaneous urinary evacuation, and makes urethral catheterization difficult. In median lobe enlargement the normally straight prostatic urethra becomes definitely, and sometimes abruptly, curved.

The two *lateral lobes* arise as tubular outgrowths from the prostatic furrows on the lateral walls of the urethra. They expand laterally, anteriorly, posteriorly and upward until they occupy most of the base or upper portion of the prostate. During development they are separated from the median lobe by fibrous partitions not present in the adult gland. As they grow they nearly approximate one another anterior to the urethra, especially in the inferior part of the gland near its apex. Hypertrophy of the lateral lobes causes urinary

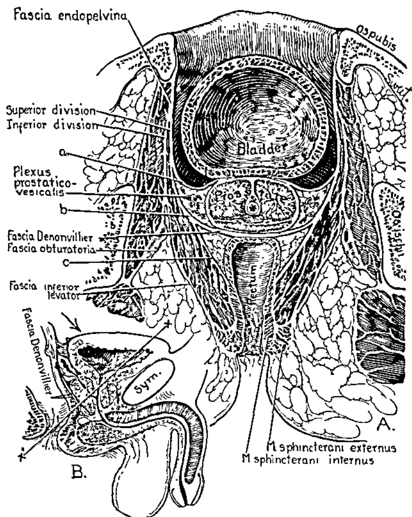


Fig. 600. OBLIQUE TRANSVERSE SECTION THROUGH THE MALE PELVIS AND PERINEUM.

The inset, *B*, is a sagittal section through the male pelvis and perineum; the line *x-x'* is the level at which the main drawing was made; *a*, *b*, *c* represent the superior, middle, and inferior divisions of the superior or rectovesical division of the pelvic fascia.

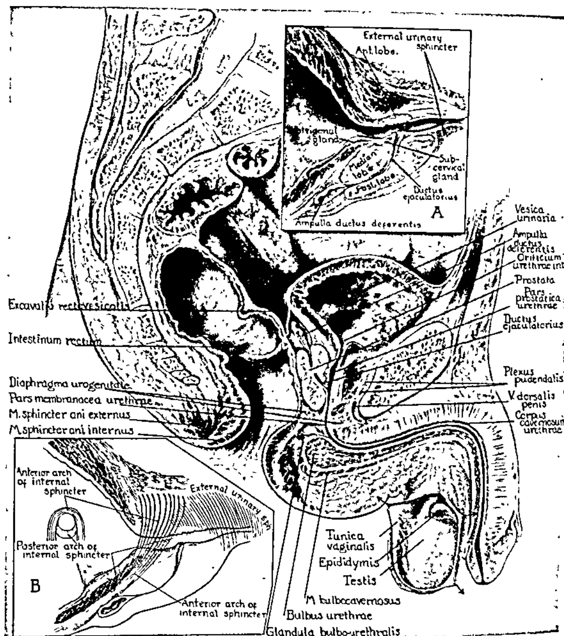


Fig. 599. SAGITTAL SECTION THROUGH THE MALE PELVIS, PERINEUM AND EXTERNAL GENITALS. *A*, Sagittal section through the neck of the bladder and the prostate; *B*, diagram of the musculature at the vesical orifice (After Wesson.)

hypertrophied glandular elements of the prostate, injury to the periprostatic venous plexuses must be avoided. The capsule and sheath must not be damaged, lest there be urinary extravasation into the extraperitoneal tissues of the pelvis.

DEVELOPMENT OF THE PROSTATE; MECHANISM OF URINARY OBSTRUCTION. For a proper appreciation of the mechanism of urinary obstruction from glandular hypertrophy, a knowledge of the development of the prostate is essential (Fig. 601). In intrauterine life longitudinal depressions appear on the walls of the urethra just inferior to the bladder. By a process of budding, these depressions are elaborated into a number of glandular masses or lobes which penetrate the surrounding muscle and connective tissue to form the prostate gland.

The lobules forming the *anterior lobe* bud from the anterior wall of the urethra. The glandular elements are few and gradually disappear until, at birth, the lobe of the prostate gland thus formed has no surgical significance, since its few glandular elements do not encroach upon the lumen of the urethra.

sphincter. As they are proximal to the internal sphincter, their position is most important, since even a slight increase in their size may cause marked interference with the passage of urine from the bladder.

The small nodules of *subtrigonal gland tissue* lie beneath the mucosa of the middle of the bladder trigone and near its apex. Although their size is comparatively insignificant, those near the apex of the trigone occupy a strategic intravesical position. A slight hypertrophy may encroach on the lumen of the vesical orifice

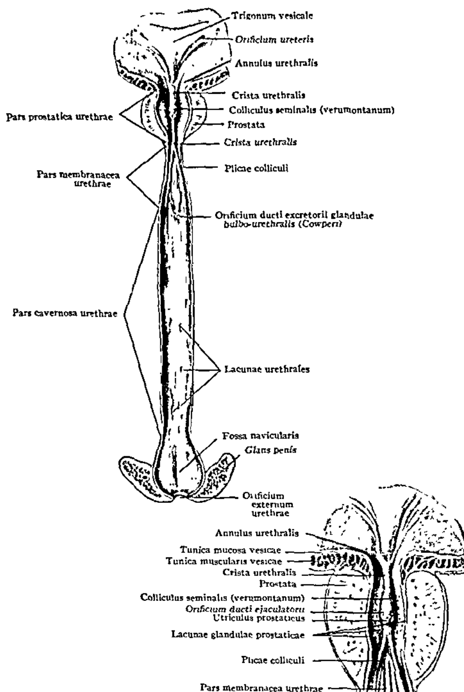


Fig. 602. ANTERIOR ASPECT OF THE NECK OF THE BLADDER AND POSTERIOR ASPECT OF THE URETHRA.
The inset shows the details of the prostatic urethra.

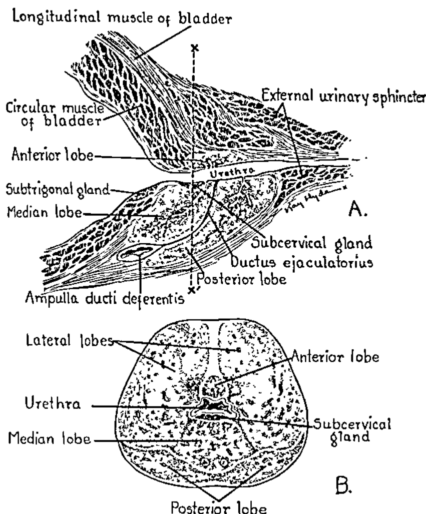


Fig. 601. *A*, MIDSAGITTAL SECTION THROUGH AN EMBRYO TO SHOW THE STRUCTURES AT THE NECK OF THE BLADDER. *B*, CROSS SECTION AT THE NECK OF THE BLADDER AT THE LEVEL OF *x-x'* IN DRAWING A.

These drawings illustrate the development of the lobes of the prostate. (After Lowsley.)

obstruction by lateral encroachment on the prostatic urethra. If one lobe greatly exceeds the other in size, the urethra is deviated laterally and is increased in length.

The tubules of origin of the *posterior lobe* arise in the posterior wall of the urethra inferior to the orifices of the ejaculatory ducts, and grow superiorly to occupy a plane behind the ducts. As they grow upward toward the base of the bladder, they are both posturethral and postspermatic. This lobe in the ultimate gland is separated definitely from the lateral and median lobes and the ejaculatory ducts by fibrous interlobar partitions. It forms all the posterior surface of the gland and, therefore, is the lobe encountered in rectal examination. The lobe thins out toward the superior surface of the gland, and presents a median longitudinal furrow. Enlargement of this lobe rarely occurs.

In perineal prostatectomy (p. 629) it is necessary to incise the posterior surface of the prostate deeply enough to penetrate the posterior lobe completely and divide the fibrous septum anterior to it. The lateral lobes and median lobe, the true offenders in prostatic hypertrophy, are enucleated through the incision or incisions in the posterior lobe. Attempt at enucleation of these lobes through the posterior lobe is difficult if the incision is too shallow and extends only into and not through the substance of the posterior lobe. With an adequate incision both the lateral and median lobes may be removed in such a way as to leave a median bridge of tissue which contains the thickness of the posterior lobe as well as the ejaculatory ducts.

The *subcervical glands* develop beneath the mucosa of the urethra just outside the bladder, but within the confines of the internal urinary

but sweep downward inferior to and behind it. They then arch forward and mesially about the origin of the urethra in such a way as to form an arch over it. To assist in forming a sphincter about the initial part of the urethra, a few of the circular fibers of the bladder continue a short distance down the posterior and lateral walls of the urethra and form a contractile posterior arch (Wesson).

The *urethral* (*external urinary*) *sphincter* consists of concentrically placed striated muscle fibers which invest the prostatic and beginning membranous parts of the urethra distal to the anterior arch of the internal sphincter. Only toward the apex of the prostate do the fibers entirely surround the urethra, enabling them to exert a sphincter action. It is unlikely that this voluntary sphincter is the sole agent in urinary retention distal to the involuntary internal sphincter. The intrinsic involuntary muscle supply of the prostatic urethra probably plays an important role in urinary retention. The rare instances of urinary incontinence following suprapubic prostatectomy no doubt are a result of the destruction of much of the prostatic urethra and its intrinsic involuntary musculature.

Part of the explanation of the incontinence which occasionally follows the perineal removal of the obstructing masses in the prostate may be injury of the vesical sphincter from long-standing distention by the hypertrophied prostatic lobes or from operative trauma. Incontinence after this operation may be caused by external membranous urethrotomy and removal of much of the prostatic urethra and its involuntary musculature.

Surgical Considerations

PROSTATITIS AND PROSTATIC ABSCESS. Prostatitis, especially the chronic form, is a common disease, and is usually associated with some degree of seminal vesiculitis. The gonococcus is still the etiologic organism of greatest frequency, but staphylococci and coliform bacilli are not uncommon as primary or secondary invaders. The infection may extend directly from the urethra or come by way of the lymphatics or blood stream. The inflammation tends both to acute suppuration and chronicity of infection because of the imperfect drainage from the prostatic tubules. When the infecting organisms have entered a prostatic duct, edema of the walls of the duct occurs, which blocks the egress of pus formed in the deeper structures. The increased vascularity of the tissue of the gland causes swelling. The symptoms of bladder tenesmus and painful urination are caused partly by mechanical obstruction, but probably more by the spread of inflammation to the trigonal region (p. 611). The acute infection soon passes into a chronic stage. Infection persists in the glands of the prostate and in the crypts of the prostatic urethra.

In some instances a prostatic abscess may develop, in the form of either a single large cavity or of several discrete foci. The abscess usually points in the direction of least resist-

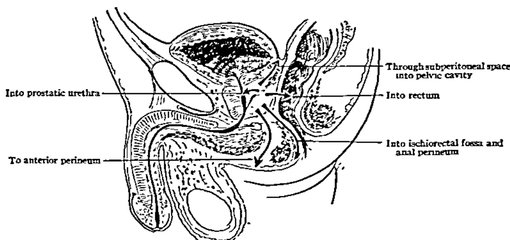


Fig. 604. PATHS OF EXTENSION FROM A PROSTATIC ABSCESS.

The arrows indicate rupture through the subperitoneal space into the pelvic cavity, into the rectum, into the ischiorecta fossa and anal perineum, and into the prostatic urethra.

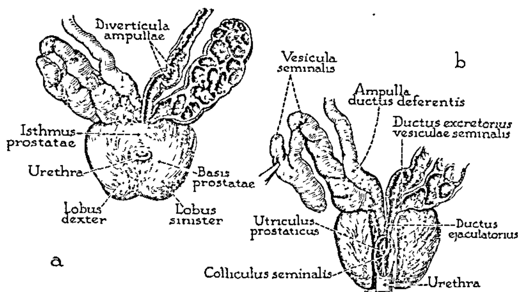


Fig. 603. PROSTATE GLAND, SEMINAL VESICLES AND DUCTS AND EJACULATORY DUCTS, VIEWED FROM THE FRONT AND ABOVE.

a, Prostate separated from the urinary bladder; left seminal vesicle and duct opened. *b*, Seminal vesicle further dissected, the ejaculatory duct and urethra exposed by removal of a wedge-shaped piece of the prostate gland. (After Spalteholz.)

and form a decided obstruction to urinary outflow. The tubules, in some instances, become so pedunculated as to lie almost free about the vesical orifice, and are in a position to block it in a ball-valve fashion as effectively as a much hypertrophied prostate.

PROSTATIC URETHRA. The prostatic urethra, normally about 3 cm. long, traverses the gland from base to apex, that is, from the internal urethral orifice to the superior layer of the urogenital diaphragm (triangular ligament). There it is continuous with the membranous portion (Fig. 602). It does not follow the axis of the prostate, but lies much nearer the anterior than the posterior surface. The lumen of the urethra, although admitting of considerable dilation, normally is obliterated by the approximation of its anterior and posterior walls. It appears in cross section as a horizontal slit, save where the seminal colliculus (verumontanum) bulges forward from the posterior urethral wall. In lateral lobe hypertrophy, pressure of the lobes transforms the slit into an anteroposterior fissure.

The *urethral crest* extends along the posterior wall or floor of the urethra from its origin on the vesical trigone (p. 611) to its termination at the membranous urethra (Figs. 602, 603). On each side of the crest is a depressed fossa, the *prostatic sinus*, the floor of which is perforated by numerous apertures, the *orifices of the prostatic ducts*. The *seminal colliculus* (*verumontanum*), the greatest prominence of the urethral crest, lies over the middle of the prostatic urethra where the lumen of the channel, because of the forward projection of the colliculus, appears crescentic in outline (Fig. 602). It is surmounted by the slitlike opening of the *prostatic utricle*. The cul-de-sac of the prostatic utricle is directed backward and upward a variable distance (10 to 12 mm.) into the prostate. Upon the seminal colliculus, and lateral to the edges of the lips of the utricle, open the *orifices of the ejaculatory ducts*. Seminal colliculitis (verumontanitis) may cause constriction or obliteration of the ejaculatory ducts.

Much clinical interest attaches to the relations of the urethra with the prostate, for chronic urethral infection involves the prostatic ducts opening at different levels into the canal. When the inflammation is propagated to the openings of the ejaculatory ducts, a deferentitis or an epididymitis may result. It is from infection localized in the prostatic urethra that prostatic abscesses arise.

INTERNAL AND EXTERNAL URINARY SPHINCTERS. The *vesical* (*internal urinary*) *sphincter* (Fig. 599) is derived from the outer longitudinal and middle circular muscle layers of the bladder. Certain of the longitudinal muscle bundles, after winding about the convexity of the bladder, do not end at the vesical orifice,

thrombophlebitis in the veins of the periprostatic plexus is a serious complication.

Deliberate evacuation of a prostatic abscess can be performed through the *perineal incision* (devised for prostatectomy) (p. 629). Should the abscess be intraprostatic, the posterior surface of the gland is reached without encountering pus. Lateral incision through the posterior lobe allows exploration of the abscess cavity, and blunt dissection serves to explore its wall and break down intervening septa. If the abscess has become periprostatic, pus is encountered before the prostate is reached. Lateral and retroprostatic collections are evacuated easily, but supraprostatic suppuration requires freeing of the posterosuperior aspect of the gland.

The abscess may be evacuated into the urethra through a *median perineal urethrotomy* incision. A finger is introduced into the membranous urethra and carried into the prostatic urethra. A knife is directed along the palpating finger, and an incision is made through the wall of the prostatic urethra and the intervening normal prostatic tissue into the abscess cavity. The abscess may be made to open into the urethra by fulguration of the posterior wall of the prostatic urethra through the cystourethroscope.

PROSTATECTOMY. The object of prostatectomy for nonmalignant enlargement of the gland is to remove permanently the cause of obstruction to urinary outflow, allow satisfactory emptying of the bladder, and, at the same time, preserve vesical control (Figs. 605 to 607). Preservation of the ejaculatory ducts is desirable, but should not jeopardize the object of the operation. The obstacle to urination usually is hypertrophy of the prostatic glandular elements. Prostatectomy for malignancy of the prostate entails radical removal of the gland. The prostate may be approached for removal in four ways, i.e., suprapubic, perineal, transurethral or retropubic.

Suprapubic intracapsular adenectomy is performed by opening the bladder through the suprapubic incision (p. 613), with the patient in the Trendelenburg position. The mucous membrane which covers the upwardly projecting lobes of the prostate is incised, the index finger is introduced into the rent thus made, and enucleation of the median and lateral lobes is performed (extraurethral method; Fig. 605). The same object may be accomplished by

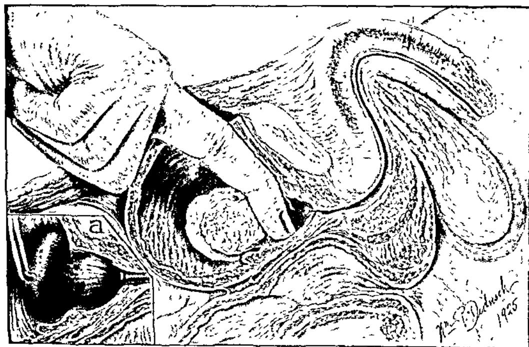


Fig. 606. SUPRAPUBIC PROSTATECTOMY BY THE INTRAURETHRAL METHOD OF ENUCLEATION.

A finger is introduced into the prostatic urethra as far as the apex, and tears through the mucous membrane in front of the lateral lobes on each side; the finger is shown pushing the median lobe of the prostate backward into the bladder along with the lateral lobes. Enucleation may be in one piece or separately, depending on how closely attached the lobes are to each other. Inset *a* shows the Hagner bag drawn into the cavity to stop hemorrhage. (From Young: Practice of Urology.)

ance and ruptures into the urethra (Fig. 604). An abscess not opening into the urethra may form a periprostatic suppuration which can extend in many directions. The dense investment of pelvic fascia resists its progress through the peritoneum into the pelvic cavity, but the collection of pus may lie above the prostate and tend to localize about the seminal vesicles. It scarcely can reach the most anterior part of the perineum because of the strong urogenital diaphragm. To reach the perineum, it points toward the rectum, from which it is separated by the less resistant rectovesical fascia. It may erode this fascia and invade the rectum, or be guided by the fascia into the perineum through the interval between the urogenital diaphragm and the anus. The abscess sometimes fuses forward and breaks through the pubovesical ligaments into the prevesical space (of Retzius). The periprostatic diffusion from the abscess may lie lateral to the gland and reach the ischiorectal fossa by invading the levator ani muscle.

The investment of the prostate in an unyielding capsule serves, in part, to explain the severe pain occasioned by abscess. Since the prostatic nerve supply is derived from the lower dorsal and upper lumbar segments, referred pain may occur over a large area. It is common in the back about the twelfth rib and the sacrum, and may be referred to the foot through the third sacral nerve.

To minimize the amount of prostatic tissue destroyed and the danger of extension of infection, the abscess should be evacuated immediately upon its discovery. A spreading



Fig. 605. SUPRAPUBIC PROSTATECTOMY BY THE EXTRAURETHRAL METHOD OF ENUCLEATION.

Enucleation is begun after breaking through or incising the mucous membrane at the peripheral edge of the intravesical projecting prostatic lobes (see inset *a*). Through this opening the finger is inserted and the enucleation is carried out laterally and posteriorly, as shown in the main drawing. Lateral, median and sometimes anterior hypertrophied tissue is removed in one mass. The final procedure is to break through the urethra near the apex of the prostate. Inset *b* shows the urethra ruptured just proximal to the ejaculatory ducts and the torn edge of the vesical mucosa adjacent to the cavity. (From Young: Practice of Urology.)

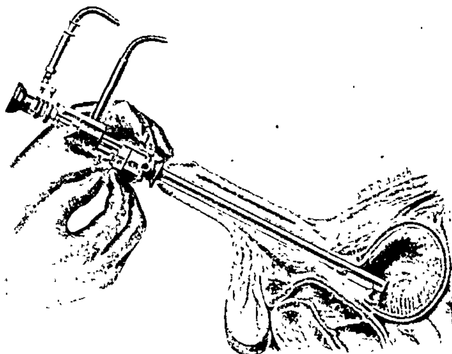


Fig. 608. TRANSURETHRAL PROSTATECTOMY.
Kirwin rectoscope in position for removal of hypertrophic middle lobe. (From Lowsley and Kirwin: Clinical Urology. Baltimore, Williams & Wilkins Company.)

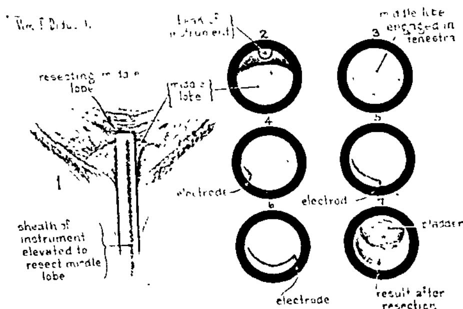


Fig. 609. TRANSURETHRAL PROSTATECTOMY (CONTINUED).
1, The bladder at the vesical orifice. The cutting electrode is downward and cannot be seen. *2 to 6, Cystoscope views of* resection carried out on the middle lobe. 7, The result after resection, showing the bladder and a large *groove through the* prostate. (From Lowsley and Kirwin: Clinical Urology. Baltimore, Williams & Wilkins Company.)

plunging the finger into the prostatic urethra to the apex of the gland and enucleating the offending lobes from that position (intraurethral method; Fig. 606). While the prostatic masses are being removed, the bladder floor may be steadied with two fingers in the rectum pressing the prostate forward in the direction of the suprapubic wound. When the enlargement is caused by an adenoma, the true prostatic tissue is thinned out and compressed against the capsule. Enucleation is comparatively easy, and the periprostatic venous plexus is not in danger.

When enlargement results from hypertrophy of the fibrous tissue components, the whole gland, including its capsule, must be enucleated from the sheath which contains the prostaticovesical venous plexus (*suprapubic extracapsular enucleation*). In extracapsular enucleation the finger is insinuated into the interval between the capsule and the sheath. The sheath may be likened to the peel of an orange, and the capsule to the covering of the individual segments. To define the cleavage interval further, the finger is swept around one side of the prostate and then the other, the pad of the finger hugging the capsule to avoid injury to the sheath. In this procedure some prostatic veins are torn through as they pass outward to join the prostaticovesical plexus. The prostate remains fixed

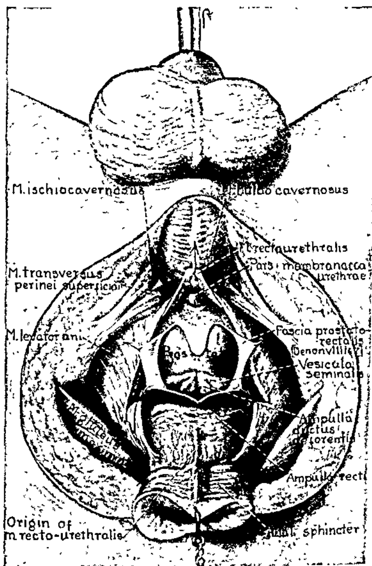


Fig. 607. PROSTATE AND SEMINAL VESICLES EXPOSED THROUGH THE PERINEAL APPROACH.

The anobulbar raphe and the rectourethralis muscle are divided; the interlevator space is widened by transverse incision into the levator ani muscles; pressure exerted on the intravesical tractor exposes the structures at the neck of the bladder, which are seen through the anterior layer of the prostatorectal fascia (of Denonvilliers). Attention is called to the sharp anterior angulation of the ampulla of the rectum.

For *perineal prostatectomy* the patient is placed in the exaggerated lithotomy position, and a sound is passed into the bladder. A curved or inverted V-shaped incision is made anterior to the anus and deepened to the central tendinous point of the perineum, the lateral limits of which are defined by blunt dissection. The central tendon is divided in the line of the skin incision, exposing the interval between the rectum and the corpus cavernosum of the urethra (bulb). After the rectourethral muscle has been divided the bulb can be drawn forward and the rectum backward (Fig. 607). The prostate then is exposed in the depth of the wound. The urethra is incised at the apex of the prostate by cutting down on the sound. The incision must not injure the urethral sphincter. The sound is withdrawn, and a prostatic tractor is passed into the bladder through the incision in the urethra. By use of the tractor the prostate is levered downward and backward into the perineal wound, and the

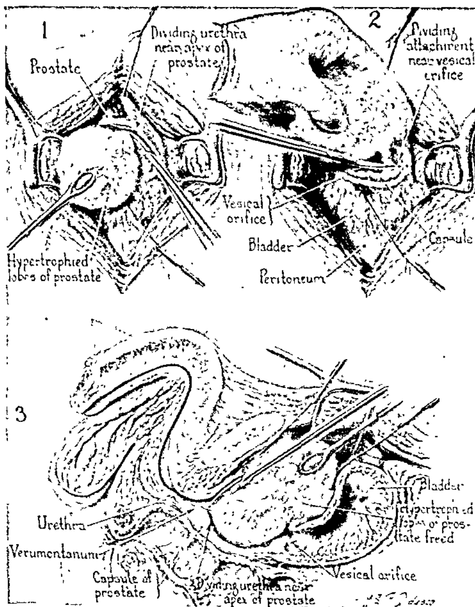


Fig. 611. RETROPUBIC PROSTATECTOMY (CONTINUED).

1 and 3, Hypertrophic lobes of the prostate have been freed by blunt dissection with the finger and elevated. The prostatic urethra near the apex of the gland is being divided. 2, Division of the attachment at the vesical orifice. Note that the operation is all below the bladder. (From Lowsley and Gentile: J. Urol., 59: 281–96, 1948.)

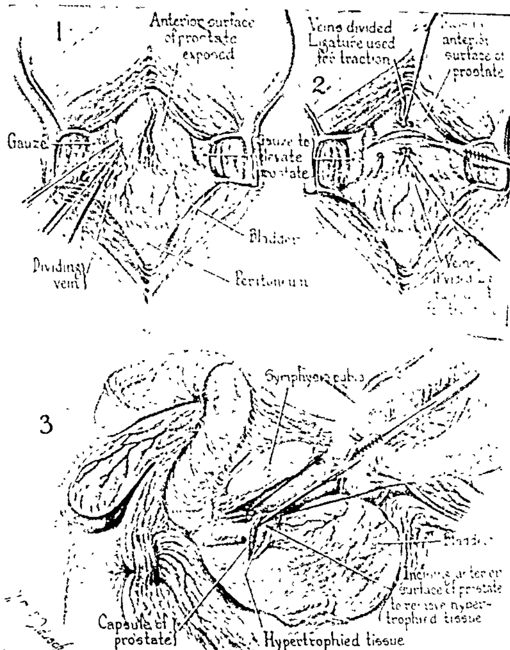


Fig. 610. RETROPUBIC PROSTATECTOMY.

1, Lower abdominal midline incision, with the rectus muscles retracted laterally. The peritoneum is reflected upward from the bladder and the perivesical fat stripped away from the symphysis and anterior surface of the prostate gland. Gauze is placed on either side of the prostate to elevate that structure. 2, The anterior veins are ligated carefully, and ligatures used for traction. 3, Sagittal view showing the anterior capsule of the prostate being incised 1 cm. above the vesicoprostatic junction (From Lowsley and Gentile: J. Urol., 59: 281–96, 1948.)

only by the distal end of the prostatic urethra, which, at this stage, is torn across where it pierces the urogenital diaphragm. If the interval between the sheath and the capsule is not defined and the sheath is broken through, severe hemorrhage from the veins of the prostaticovesical plexus results.

In partial or complete removal of the prostate the prostatic urethra is replaced by a fibrous sac: by the prostatic capsule in adenectomy; and by the prostatic sheath in extracapsular enucleation. The neck of the bladder opens into the sac above, and the urethra descends from it below. The cavity, filled at first with blood and urine, soon collapses, and the walls gradually become lined by mucous membrane which grows downward from the bladder and upward from the urethra.

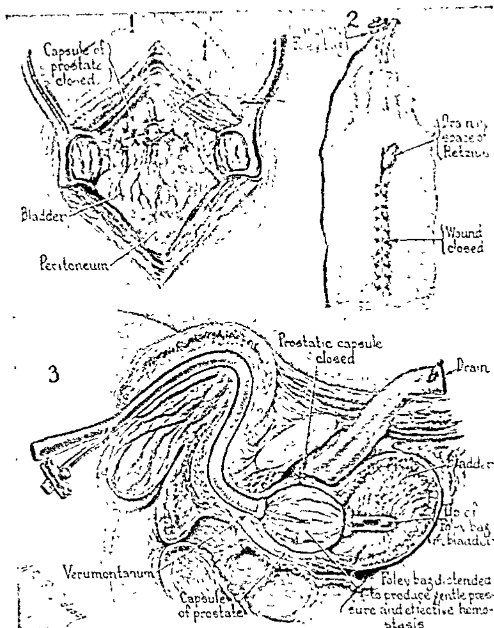


Fig. 613. RETROPUBIC PROSTATECTOMY (CONCLUDED).

1, Prostatic capsule closed. Ligatures on the anterior veins are tied together to reinforce the closure. 2, The midline wound closed, with a drain from the space of Retzius brought out at the lower angle. 3, Sagittal view of the completed operation. The distended Foley catheter now occupies the previous position of the hypertrophic prostatic lobes and produces gentle pressure and effective hemostasis. The anterior prostatic capsule has been closed. The tip of the Foley catheter drains the bladder. There is an anterior drain to the space of Retzius. (From Lowsley and Gentile: J. Urol., 59: 281–96, 1948.)

opinion, however, recognizes both the value and the limitations of this procedure. Lowsley and Kirwin believe that the method is applicable to (1) intrusion of a slightly or moderately enlarged middle lobe, with or without slight lateral lobe enlargement; (2) slightly or moderately enlarged lateral lobes without median lobe enlargement; (3) subcervical gland hypertrophy causing frequency; (4) certain cases of carcinoma of the prostate with obstruction at the vesical neck; (5) conditions of marked renal impairment or other grave disabilities making the chief aim that of establishing renal drainage; (6) senile patients unable to undergo open operation. Needless to say, a thorough knowledge of the structures seen and what

offending prostatic tissue, usually the median and lateral lobes, is removed intracapsularly through one or two vertical incisions through the posterior lobe of the gland.

A central wedge, containing the prostatic urethra and the ejaculatory ducts, is preserved, if possible. The perineal approach avoids an extensive wound in the base of the bladder, and dependent drainage is obtained through the urethrotomy incision. Dependent drainage is important when chronic cystitis is a complication.

Transurethral resection of the prostate (Figs. 608, 609) has been developed as a result of great improvement in instruments and electrical currents to the point that some urologists feel that it should replace suprapubic and perineal prostatectomy entirely. The general

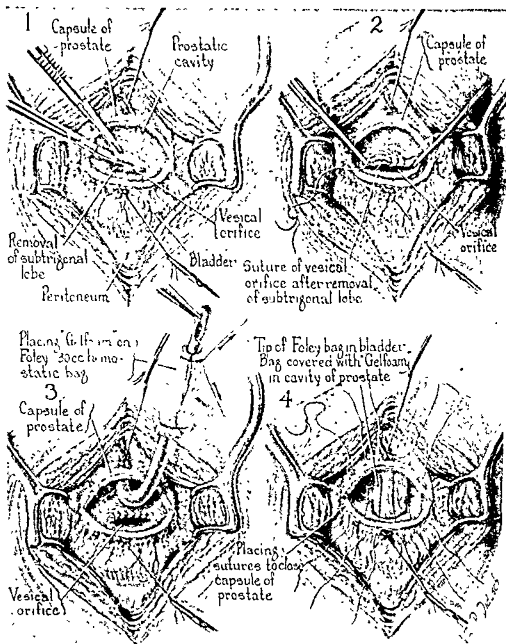


Fig. 612. RETROPUBIC PROSTATECTOMY (CONTINUED).

1, Removal of the hypertrophied subtrigonal lobe from the posterior lip of the vesical orifice. 2, Closure of this defect. 3, Coagulant Gelfoam wet with thrombin placed around a 30-cc. hemostatic bag of a no. 24 Foley catheter passed through the penile urethra. 4, The tip of the catheter has been inserted through the vesical orifice into the bladder. The bag, covered with Gelfoam, is lying in the prostatic cavity. Interrupted sutures of catgut are placed for closing of the prostatic cavity. (From Lowsley and Gentile: J. Urol, 59: 281–96, 1948.)

CHAPTER 19

Soft Parts Lining the Female Pelvis

The female pelvis is differentiated sharply from the male pelvis by its intrapelvic genitalia: the ovaries, uterine (fallopian) tubes, the uterus and its ligaments, the vagina and rectum. As the uterus in its development rises upward and forward from the extraperitoneal space, it lifts the serosa into a peritoneal covering for the uterine fundus and the contents of the two broad ligaments (Frontispiece, Part V). The broad ligaments, with the uterus, form a transverse partition dividing the pelvis into two separate cavities, the vesicouterine and the rectouterine culs-de-sac or excavations (Fig. 614).

Peritoneum

The peritoneal cavity is the space revealed by incising and reflecting the abdominal wall (Figs. 617, 618). It is lined by a serous membrane, the peritoneum, which, upon its internal free surface, is smooth and glistening, and upon its external surface is roughened for attachment to the subserous or extraperitoneal connective tissue, intervening between the

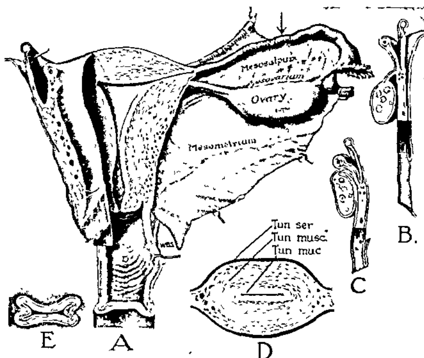


Fig. 614. THE BROAD LIGAMENT AND THE FEMALE INTERNAL ORGANS OF GENERATION, SEEN FROM BEHIND.

The broad ligament has been spread out on the right; on the left it has been cut and turned backward. The uterus and the vagina are partially opened. *B*, Schematic vertical section of the broad ligament at the level of the arrow in *A*; the mesometrium and the mesovarium have been spread apart. *C*, The same, with the portions of the ligament and the ovary in their normal relations. *D*, Transverse section of the body of the uterus, showing the 3 layers, or tunics (serous, muscular and mucosal). *E*, Transverse section through the lower portion of the vagina; the lumen is compressed by the vaginal columns.

they look like through the resectoscope is needed to perform the operation and avoid its hazards.

Retropubic prostatectomy has recently been revived by Millin of London and is being given a trial by urologists because of the direct anatomic approach, simplicity of execution, leaving the pelvic floor intact, and a high percentage of patients with good urinary control and sexual function. The illustrations (Figs. 610 to 613) well portray the anatomy and steps of the procedure.

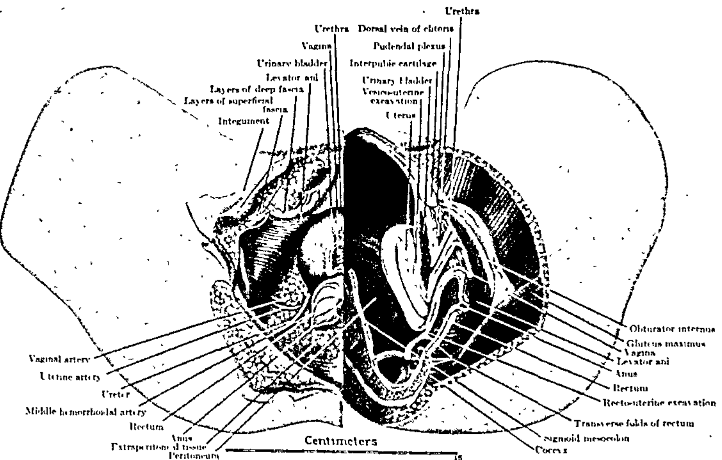


Fig. 616. STRUCTURES OF THE FEMALE PELVIS, FROM THE LEVEL OF THE MUSCULATURE OF THE PELVIC DIAPHRAGM TO THAT OF THE VISCERAL LAYER OF THE PERITONEUM; SEEN IN HEMISECTION FROM THE INTERIOR ASPECT.

On the right half the levator ani muscle has been turned outward to show the viscera together with the subserous (extraperitoneal) tissue in which they and their vessels and nerves are lodged. The peritoneal and diaphragmatic relations of organs are demonstrated on the specimen's left half. The serous layer is reflected over the pelvic viscera at a high level, being carried (in the midline) from the superior surface of the urinary bladder to the uterus anteriorly and from the vagina posteriorly to the contiguous surface of the rectum.

peritoneum itself and the fascial lining of the abdominal parietes.

Whereas, in the abdominal cavity proper, *the parietal peritoneum is reflected outward* upon portions of the alimentary tract in the form of a complicated series of supporting folds or mesenteries, in the pelvic division of the cavity it is for the most part merely carried over the upper surfaces of pelvic organs, adapting itself to the inequalities produced by them (Figs. 615, 616). By their presence the peritoneum is prevented from descending to the level of the pelvic diaphragm; it passes into the lesser pelvis from the anterior abdominal wall downward to the upper surface of the urinary bladder; therefrom it is carried over the uterus and, extending lateralward on the uterine appendages, reaches the lateral wall of the pelvis *as the broad ligaments; from the* posterior surface of the uterus and its ligaments the peritoneal layer is next carried upward upon the front of the rectum, where it attains the posterior abdominal wall (Fig. 617).

In passing downward into the lesser pelvis to clothe the upper surface of the bladder, the peritoneum is *elevated over the intra-abdomi-*

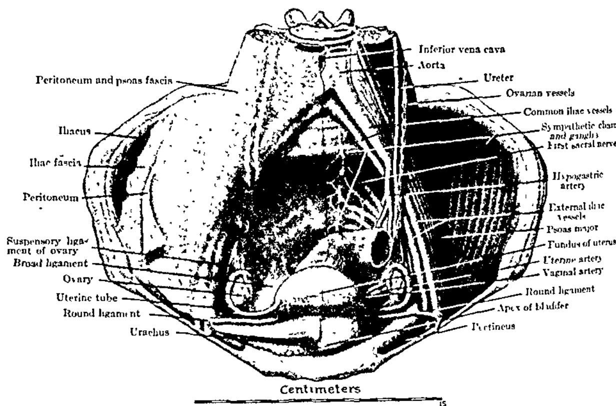


Fig. 615. FEMALE PELVIS, SHOWING THE VISCERAL AND PARIETAL STRUCTURES IN ANTERIOR VIEW.

On the left half of the specimen the peritoneum and fascia have been removed to expose the parietal musculature, the pelvic viscera and certain of the blood vessels.

The urinary bladder is situated behind the bodies of the pubic bones and in front of the vagina; it rests upon *the funnel-*shaped pelvic diaphragm. By these structures the organ is molded to the form of a three-sided pyramid, the apex or vertex of which is continuous with the middle umbilical ligament, which extends upward on the abdominal wall to the umbilicus. The base or fundus of the bladder rests against the anterior wall of the vagina (see Fig. 617).

The anterior or inferior surface of the body of the uterus rests upon the urinary bladder; the posterior or superior surface is in contact with the mesenterial portion of the digestive tube. The relations of the cervix of the uterus are demonstrated in Figure 616, which also depicts peritoneal relationships of urinary bladder, uterus, vagina and rectum.

The uterine (fallopian) tubes emerge from the wall of the uterus at the junction of the body and fundus. Except for a short intramural course, the tubes are enclosed in the free edge of the broad ligament. At the lateral extremity the fimbriated end of each tube lies in relation with the medial surface of the ovary.

The tubal extremity, or upper pole, of the ovary is attached at the pelvic brim by suspensory ligament (of which the constituent blood vessels are exposed on the specimen's left half). The uterine extremity (lower pole) is fastened to the adjacent lateral margin of the uterus by the proper ligament of the ovary. *The lateral surface of the ovary is in direct* contact with the parietal peritoneum of the pelvis, where this layer is depressed to form a shallow fossa in the angle between the diverging external iliac and hypogastric vessels. The medial surface, where not covered by the uterine tube, is exposed to the intestines

as the anterior layer of the broad ligament (Fig. 615); the shallow, troughlike recess thus formed is the vesicouterine excavation (Fig. 616). The peritoneal layer next covers the fundus of the uterus, investing all of the posterior uterine, and a small, upper segment of the vaginal, wall; from the uterus it is again extended lateralward, to form the posterior layer of the broad ligament of the uterus. From the uterus and the ligament the peritoneum passes to the front of the rectum, forming a deeper sac (Fig. 616), the rectouterine excavation (rectouterine pouch, cul-de-sac or pouch of Douglas). The peritoneum reaches the rectum at or near the junction of its lower and middle thirds (Fig. 617); in typical instances the peri-

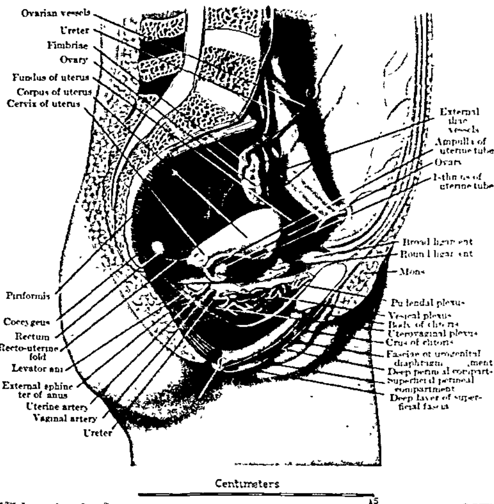


Fig. 618. FEMALE PELVIC AND PERINEAL ANATOMY, DEMONSTRATED IN PARAMEDIAN SECTION.

Showing especially the supporting structures of the uterus, the musculature of the pelvic diaphragm, the space of the ischiorectal fossa and the fascial boundaries and contents of the perineal compartments.

The ovarian vessels (constituents of the suspensory ligament of the ovary) are demonstrated by lifting them through an incision in that part of the parietal peritoneum which covers the psoas major muscle; the round ligament, transected on the specimen's right, is contained in a peritoneal fold on the anterior aspect of the broad ligament. The proper ligament of the ovary is out of view; in the form of a rounded cord this supporting element passes from the lateral margin of the uterus to the uterine extremity of the ovary.

The subperitoneal space, bounded inferiorly by the pubic diaphragm, is largely occupied by the venous plexuses which are associated with the urinary bladder, uterus and vagina and rectal segment of the digestive tube.

The ischiorectal fossa (here freed of its normal content of fatty subcutaneous tissue) extends anteriorly between the pelvic and urogenital diaphragms. The sphincteric musculature of the latter diaphragm is contained in the space of the deep perineal compartment; the superficial perineal compartment contains the erectile tissue of the clitoris and the muscles which invest these spongeous structures.

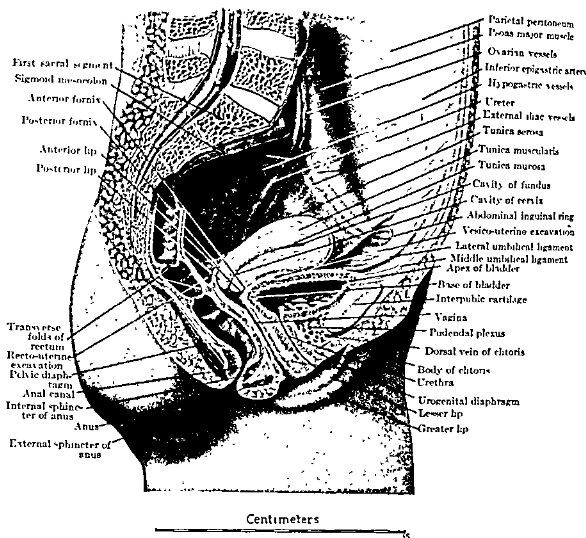


Fig. 617. FEMALE PELVIS, IN MEDIAN SAGITTAL SECTION.

Demonstrating especially the interrelationship of the organs and the extent to which each is invested, in the midline, by the peritoneum (*tunica serosa*).

The inferior surface of the urinary bladder is related to the pubic symphysis and to the pudendal plexus of veins which intervenes between the bladder and the pelvic diaphragm; superiorly it is covered by peritoneum; posteriorly the urinary bladder and the urethra are related to the vagina.

The uterus, in the normally anteverted position, overlies the urinary bladder in front; it is in contact with the rectum behind. The vagina, forming an obtuse angle with the long axis of the uterus, continues downward between the rectum and the urethra.

The rectum, which extends from the sigmoid colon, descends through the lesser pelvis to an inferior opening, the anus. The rectum follows the curve, concave forward, formed by the pelvic surface of the sacrum and coccyx.

The peritoneum is reflected from the superior surface of the urinary bladder to the vesical surface of the body of the uterus, forming the vesicouterine excavation. Covering the fundus and intestinal surface of the uterine body, the peritoneum next invests the fornix of the vagina. Therefrom the serous layer is carried upward on the rectum, the slitlike space thus produced being the rectouterine excavation (or cave of Douglas). Reflected from each side of the uterus, the layers of peritoneum, meeting back-to-back, continue lateralward as a quadrangular duplication to the pelvic wall; there they deviate from each other, becoming parietal peritoneum.

nal, cordlike remnant of the allantois (urachus or middle umbilical ligament) to form the middle umbilical fold, to each side of which lies a lateral umbilical fold over the obliterated hypogastric artery (Fig. 619); and as the peritoneum descends from the lateral pelvic wall to the bladder, on each side of the organ a shallow depression is formed, termed the paravesical fossa. Traced over the posterior border of the bladder, the peritoneum ascends to cover the vesical surface of the body of the uterus, from which it is continued lateralward

toneum covers the middle third in front of the tube, while in the upper third it clothes the sides as well. The layers of the two sides then meet above to form a mesenteric support for the sigmoid colon. Variations in disposition of this serous covering are not uncommon (Fig. 573). In partially investing the rectum, the peritoneum forms paired pouches, the pararectal fossae, bounded on each side by a crescentic fold of peritoneum, the rectouterine fold (of Douglas), which corresponds to the sacrogenital fold in the male and contains the uterosacral ligament.

Extraperitoneal Tissue

This layer of subserous areolar tissue (extraperitoneal, subperitoneal or retroperitoneal tissue) forms a dense, cobweb-like packing containing a varying amount of fat, which intervenes between the fascia on the inner surface of the abdominal and pelvic musculature and the peritoneum, which lines the contained cavity (Fig. 615). In the abdominal cavity proper the tissue is carried forward between the layers of the supporting mesenteries to the viscera, and within it course the splanchnic branches of the vascular and nervous systems. In general, on the abdominal parietes the peritoneum is rather closely applied to the fascia; consequently the subserous tissue forms a relatively thin layer. In the pelvis, however, the peritoneum is reflected from the wall to the organs at a level considerably higher than the point at which the parietal fascia is continued medialward on the upper surface of the pelvic diaphragm (Fig. 617). The considerable subperitoneal space thus produced is filled with the adipose areolar tissue which forms a bed around the pelvic organs over which the peritoneum is draped. It encloses much of the rectum, which possesses only a partial peritoneal covering; it forms a bed for the bladder, investing the organ below and behind; it extends upward along the sides of the uterus, between the layers of the broad ligament, there forming the connective tissue matrix, or parametrium, in which are embedded the uterine tubes and the ovaries, with their vessels and nerves (Fig. 614).

Parietal Musculature and Fascia

The muscles which cover the walls and which constitute the floor of the pelvis minor belong to two groups: those of the lower extremity, the obturator internus and the piriformis; and those which form the pelvic diaphragm, namely, the coccygeus and the levator ani. The fasciae of these muscles are continuous with one another, and likewise with the transversalis fascia of the abdomen and the aponeurotic layers of the perineal compartments; they also provide fibrous coverings for the pelvic organs.

The piriformis muscle is triangular and lies flattened against the posterior wall of the pelvis minor (Figs. 622, 623). It originates by three or more processes: lateral to the second, third and fourth anterior sacral foramina; becoming narrower and more rotund, it leaves the pelvis through the upper part of the greater sciatic (ischiadic) foramen, for insertion into the greater trochanter of the femur. The thin fascial covering of the muscles is prolonged upon it from a sacral attachment into the gluteal region. The piriformis, together with the coccygeus muscle, closes the space in the posterior bony wall of the pelvis intervening between the ischium and sacrum (Fig. 623).

The obturator internus muscle clothes the side-wall of the pelvis minor and, like the piriformis, is flattened and fan-shaped (Fig. 622; *cf.* Fig. 623). It arises from the circumference of the obturator foramen, from which its fibers converge toward the lesser ischiadic foramen; becoming tendinous, it is joined by the two gemelli, and with them is inserted into the greater trochanter of the femur.

The fascia covering the pelvic surface of the muscle (forming the obturator fascia) is attached above to the periosteum along the arcuate line, where it is continuous with the iliac fascia as the latter covers the iliacus muscle in the pelvis major (Fig. 620); in front it is attached to the superior ramus of the pubis, and below to the pubic arch, where it forms the fascial canal (of Alcock) housing the pudendal vessels and nerves. Midway in its course the layer gives origin to the two layers of the diaphragmatic pelvic fascia (p. 642); it is carried outward with the muscle to blend with the tendon of insertion.

The coccygeus muscle and the levator ani form, with their fellows of the opposite half of the pelvis minor, the muscular constituents of the pelvic diaphragm (Figs. 619, 620). Each coccygeus muscle is thin and quadrangular, and is situated on the anterior surface of the

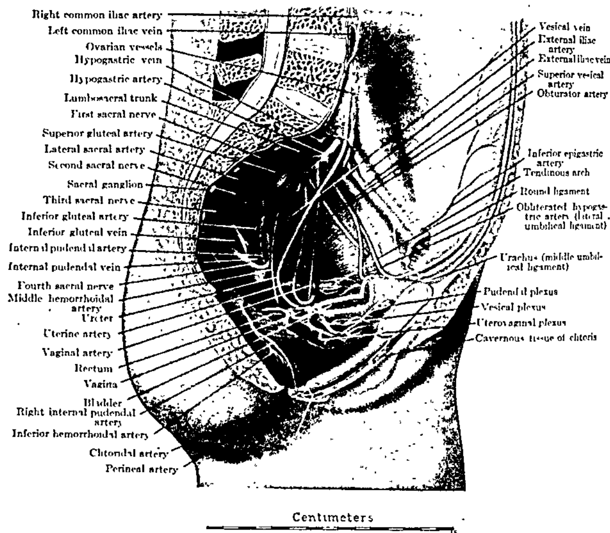


Fig. 619. BLOOD VESSELS AND NERVES OF THE FEMALE PELVIS AND PERINEUM, SEEN IN PARAMEDIAN SECTION AFTER REMOVAL OF THE PERITONEUM AND THE EXTRAPERITONEAL FATTY TISSUE.

The umbilical artery, after giving off several superior vesical branches, passes forward and upward to the anterior abdominal wall, where, as the lateral umbilical ligament, it lifts the peritoneum to produce a low fold (*plica*) of corresponding name. The vaginal artery, here a separate branch of the hypogastric, descends anterior to the ureter to reach the lateral wall of the vagina. The uterine artery, next in anteroposterior succession, first courses downward almost vertically on the wall of the lesser pelvis; then, turning medialward, the artery runs obliquely forward, crossing the ureter on its way to the uterus, which it reaches at the level of the cervix. The middle hemorrhoidal artery, which frequently arises from the internal pudendal, courses downward and medialward on the musculature of the pelvic diaphragm, to the lateral aspect of the rectum; in addition to rectal rami, the artery gives off branches to the vagina (as it does to the seminal vesicles and prostate gland in the male) and anastomoses with the superior and inferior hemorrhoidal arteries. The inferior gluteal artery, here arising from a common stem with the internal pudendal, leaves the pelvis through the infrapiriform foramen (that is, between the piriformis muscle and the sacrospinous ligament) to supply the muscles of the buttock. The internal pudendal artery accompanies the inferior gluteal through the infrapiriform foramen; passing on the posterior aspect of the ischial spine in a curving course, the artery reaches the ischiorectal fossa—there to give off the inferior hemorrhoidal artery to the anus and to send branches to the muscles and erectile bodies in the superficial and deep perineal compartments. The superior gluteal artery passes posteriorly through the suprapiriform foramen (between the posterior inferior spine of the ilium and the piriformis muscle) to take part in the supply of the 3 gluteal muscles and related structures. The lateral sacral artery descends on the pelvic surface of the sacrum, medial to the anterior sacral foramina; in addition to sending spinal rami through foramina, the artery supplies branches for the muscles and skin of the back.

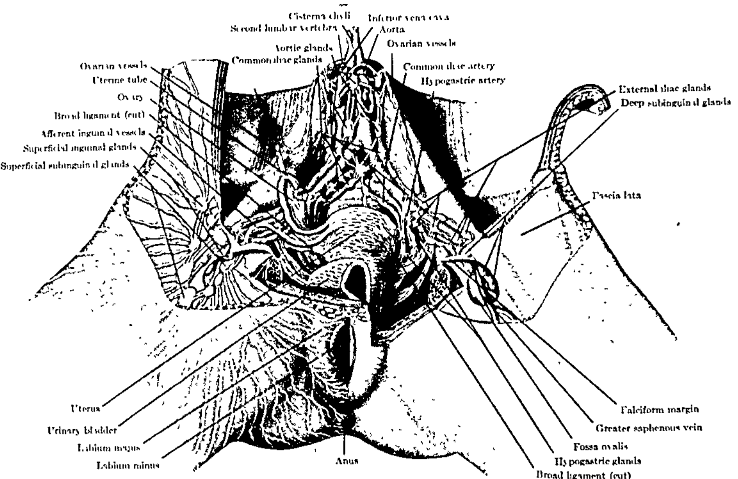


Fig. 621. LYMPHATIC GLANDS AND VESSELS OF THE PELVIS, PERINEUM AND ADJACENT REGIONS IN THE FEMALE.

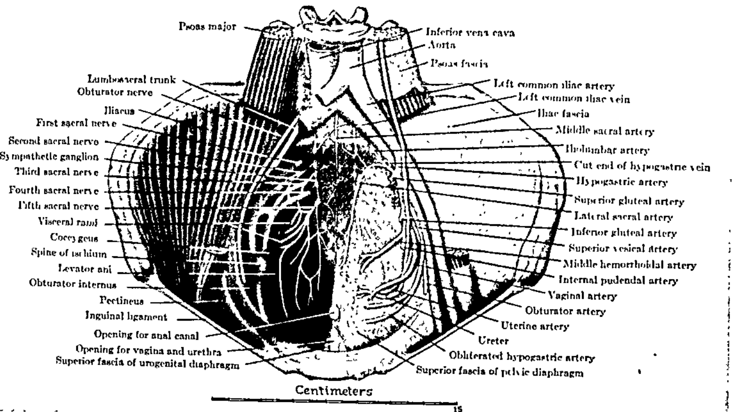


Fig. 620. BLOOD VESSELS AND NERVES OF THE FEMALE PELVIS, IN RELATION TO THE PARIETAL AND DIAPHRAGMATIC FASCIAL LAYERS; VIEWED FROM THE FRONT.

On the specimen's left the peritoneum and retroperitoneal (subserous) layers have been removed; on the opposite half of the pelvis the dissection has been carried to deeper level, with exposure of the musculature.

The blood vessels course through the subserous tissue (that is, are retroperitoneal in location); the nerves emerge from the lumbar and sacral foramina external or deep to the fascia (hence are retrofascial in position).

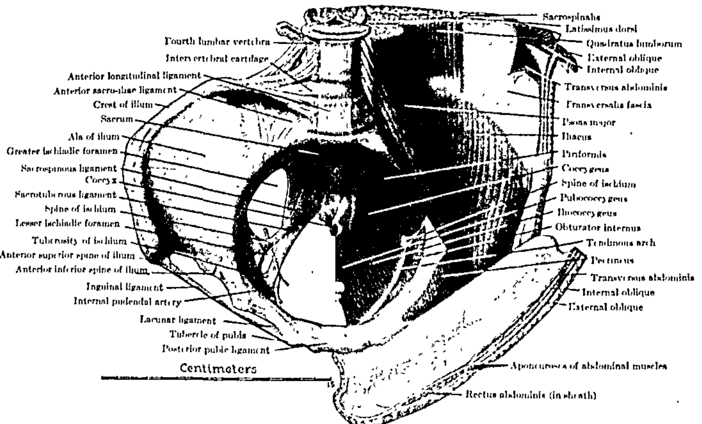


Fig. 623. SKELETAL, MUSCULAR AND LIGAMENTOUS ELEMENTS OF THE PELVIS IN THE FEMALE, TOGETHER WITH RELATED ABDOMINAL MUSCLES AND FASCIAE.

The skeletal and ligamentous structures (on the specimen's right) and the musculature, both parietal and diaphragmatic (on the left half). See also Figures 622 and 618.

The ligaments pass from the sacrum and coccyx medially to the ischial spine and tuberosity anterolaterally, thus converting the greater and lesser sciatic (ischiadic) notches into foramina. The internal pudendal artery, like the corresponding vein and pudendal nerve, passes from the pelvis into the perineum in a curving course on the gluteal aspect of the ischial spine.

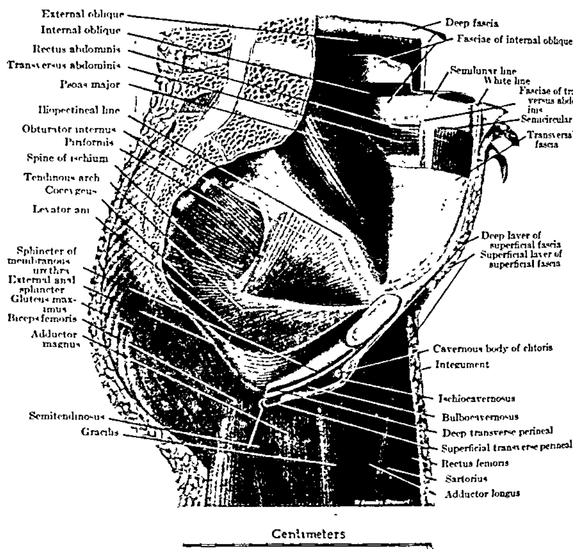


Fig. 622. MUSCULATURE OF THE FEMALE PELVIS AND PERINEUM, SEEN FROM THE RIGHT SIDE IN A PARAMEDIAN SECTION.

The psoas major muscle, from a lumbar vertebral origin, courses forward along the pelvic brim, fusing with the iliacus muscle (which arises from the pelvic surface of the ala of the ilium), the combined muscle leaves the greater pelvis under the inguinal ligament on the way to an insertion on the lesser trochanter of the femur. The obturator internus muscle arises from the inner wall of the lesser pelvis around the obturator foramen; the tendon leaves the pelvis through the lesser sciatic (ischiadic) foramen; in its descent, between the pubic and ischial attachments of the levator ani muscle, the obturator internus forms the lateral wall of the pelvic cavity cranial to the pelvic diaphragm and the corresponding boundary of the ischiorectal fossa of the perineum at a level caudal to diaphragm. The piriformis muscle arises from the pelvic surface of the sacrum; *en route* to an insertion in the trochanter fossa of the femur, the muscle passes through, and thereby closes, the greater sciatic foramen. The coccygeus, the smaller element of the muscular pelvic diaphragm, passes in short course from the spine of the ischium and the pelvic surface of the sacrospinous ligament to the lower part of the sacrum. The levator ani muscle arises in the form of a tendinous arch which begins anteriorly on the pelvic surface of the superior ramus of the pubis and ends posteriorly on the arcuate line of the ilium; coursing downward and backward, the fibers blend with the intrinsic musculature of the urethra, vagina and anal canal or, in the areas between adjacent viscera, interweave with fascicles of the opposite side.

sacrospinous ligament. The coccygeus takes origin from the spine of the ischium and, expanding, inserts into the lateral margin of the lowermost segment of the sacrum and of the upper part of the coccyx. Its thin fascial investment is continuous above with that of the piriformis, and below with the fascial layers which cover the levator ani muscles.

The levator ani muscles, and their investing fascia, together form the greater part of the pelvic diaphragm, which supports the pelvic viscera and constitutes the partition between

be predominantly fascial, containing relatively little musculature.

The fascial covering on the pelvic surface of the levator ani and coccygeal muscles is the superior fascia of the pelvic diaphragm; wherever a viscus passes through the pelvic diaphragm into the perineum, the fascia is reflected upon it to blend with the outer fibrous coats; and in accordance with the viscera to which it is related, the fascia is termed vesical, uterine or rectal layer of the endopelvic fascia. In extending outward on each side, the layer meets the parietal pelvic fascia covering the obturator internus muscle. This layer of obturator fascia is continuous at the brim of the pelvis minor with the fascial investments of the iliacus and psoas major muscles (Fig. 620); these in turn continue medialward to cover the front of the sacrum and of the lumbar vertebrae.

Along the whole length of the iliac crest, at the entrance to the pelvis major, the iliac fascia is continuous with the transversalis, which forms the general fascial lining of the abdominal parietes (Fig. 622). Between the fascia and the peritoneum, as described hereinbefore, lies the extraperitoneal fatty tissue, which in the pelvis minor fills the considerable space housing the viscera and their vessels and nerves (Frontispiece, Part V).

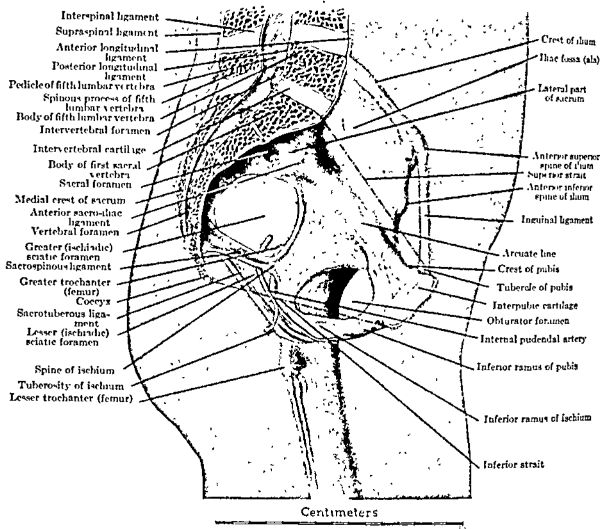


Fig. 624. SKELETAL AND LIGAMENTOUS STRUCTURES OF THE FEMALE PELVIS, VIEWED FROM THE RIGHT IN A MEDIAN SAGITTAL SECTION.

The greater pelvis is separated from the lesser by the terminal lines, which consists of the first sacral vertebra, the arcuate line of the ilium and the pectineal line of the pubis. Posteriorly it is deeply notched between the lumbar part of the vertebral column and the posterior superior iliac spine, and anteriorly between the pubic tubercle and the anterior superior spine of the ilium. On each side the cavity is bounded laterally by the ala of the ilium. Sacroiliac ligaments partially fill the deep notch behind; the inguinal ligament serves similarly in front.

On each side the lesser pelvis—that is, the portion inferior to the terminal line—is bounded below by the tip of the coccyx, the sciatic notches and the ischiopubic ramus (anteriorly to the symphysis). The broad interval between the terminal part of the vertebral column and the innominate bone is bridged across, and partially closed by, the sacrospinous and sacrotuberous ligaments.

the pelvis and the perineum (Fig. 622; *cf.* Fig. 623). Each muscle takes origin, in front, from the posterior surface of the superior pubic ramus lateral to the symphysis (Fig. 622), and behind, from the pelvic surface of the ischial spine; between these two points it has an aponeurotic origin, from the tendinous arch of the obturator fascia. The anterior fibers which constitute the pubococcygeal part of the muscle pass backward and medialward along the side of the urethra, the vagina and the anal canal; then upward, to be inserted as a tendinous plate into the anterior surface of the third and fourth sacral segments, where it may overlie the coccygeus muscle. The iliococcygeal part of the muscle, made up of the middle and posterior fibers of origin, forms, with its fellow of the opposite side, a median fibrous raphe which extends from the anal canal to the tip of the coccyx. In old subjects the diaphragm may

reaches forward to the pubic symphysis, and is continuous with the middle umbilical ligament, which extends upward on the anterior abdominal wall to the umbilicus. The body of the organ is the portion between the fundus and the vertex. The bladder is triangular in either sagittal or coronal section (Figs. 617, 699). Hence, on its under aspect, which is directed downward toward the pelvic floor, three triangular areas are distinguishable: two inferolateral areas or surfaces, and a postero-inferior surface which corresponds to the base or fundus. Each inferolateral surface looks downward and outward, and is separated from the superior fascia of the pelvic diaphragm by the veins of the pudendal plexus and the fatty subserous tissue in which they are situated (Fig. 619); they extend backward to meet the postero-inferior surface, and approximately at the point of meeting of the three in the middle line below, the internal urethral orifice is situated. The postero-inferior surface looks downward and backward, and rests against the uterus and the upper part of the vagina (Fig. 616). At the lateral extremities of the posterior surface the ureters pierce the wall of the bladder. The upper aspect, or superior surface, of the bladder looks upward and backward; it alone possesses a full peritoneal investment (Fig. 615). The serous covering is carried downward for a short distance upon the posterior surface of the organ; thence it is reflected upward upon the anterior surface of the overarching uterus to form the shallow vesicouterine excavation (Fig. 617).

The bladder, as well as the other pelvic viscera, is lodged in the extraperitoneal or subserous areolar tissue and is closely enveloped by a stronger covering, the vesical layer of the endopelvic fascia, which is reflected upon the organ from the fascia of the pelvic diaphragm.

Urethra

Course and Relations. The female *urethra* begins at the internal urethral orifice upon the most dependent portion of the bladder, and ends at the external urethral orifice as a small, vertical slit on the roof of the vestibule (Figs. 616, 617). It has a length of approximately 4 cm., and represents the prostatic and cavernous portions of the urethra in the male. The region of the bladder immediately surrounding the origin of the urethra is sometimes termed the neck; from this point the canal follows a slightly curved course downward and forward (Fig. 616); in leaving the pelvis the urethra passes through the levator ani muscle (Fig. 617); next it pierces the superior fascia of the urogenital diaphragm, and in this part of its course it traverses the deep perineal compartment, surrounded by the sphincter muscle. Its external opening is placed between the labia minora immediately in front of the vaginal orifice, and about 2 cm. behind and below the tip of the clitoris. The opening to the exterior is slitlike, and is bounded by elevated margins.

Ureters

Course and Relations. The *ureters*, throughout their course, lie beneath the peritoneum (Fig. 615), embedded in the subserous tissue (Figs. 617, 618). The pelvic portion of each ureter is about 13 cm. in length, and extends from the brim of the pelvis minor to the posterior wall of the bladder; in its downward course (Figs. 617, 619) it is directed at first posteriorly, then anteriorly, describing a curve that is concave forward and inward. The ureter lies on the internal pelvic wall, along the anterior border of the greater sciatic notch, where it forms the posterior boundary of the ovarian fossa; next it crosses the medial aspect of the hypogastric and umbilical (obliterated hypogastric) arteries, and the obturator vessels and nerves. At the level of the ischial spine the ureter turns inward upon the pelvic floor, surrounded by the venous tributaries of the vesical plexus, which separate it from the superior fascia of the pelvic diaphragm; it then traverses the lowest portion of the broad ligament, surrounded by the uterine venous plexus, and accompanied for a distance of 2.5 cm. by the uterine artery (Fig. 554). The ureter passes the supravaginal part of the cervix, about 1.5 cm. distant from its side, to reach the interval between the posterior vesical wall obliquely. On the surface of the bladder the right and left ureters are approximately 5 cm. apart.

Uterus

Form, Divisions and Relations. The *uterus* (womb) is an unpaired, hollow, muscular organ, situated in the middle of the pelvis minor, between the bladder in front and the rectum behind (Figs. 616, 617). It is partially invested by peritoneum, and is lined with mucous membrane. The uterine tubes enter its upper portion on either side, and its cavity is

CHAPTER 20

Pelvic Viscera in the Female

The female pelvis minor contains the following viscera: the rectum and the sigmoid colon; the urinary bladder, the urethra and the ureters; the uterus, the vagina, the uterine tubes and the ovaries.

Sigmoid Colon and Rectum

DEFINITION, BOUNDARIES AND RELATIONS. The sigmoid colon (pelvic colon, sigmoid flexure) is the portion of the large intestine which begins at the superior aperture of the pelvis minor, where it is continuous with the iliac part of the descending colon, and ends opposite the third segment of the sacrum by passing into the rectum (Fig. 617). The sigmoid colon enters the lesser pelvis by passing over the medial border of the left psoas major muscle, crosses the front of the sacrum first to the right side of the pelvis, and then passes back to the left, describing a characteristic S-shaped figure; on the posterior pelvic wall and near the middle line opposite the third sacral vertebra it usually turns downward to join the rectum. Like the portions of the gut between which it intervenes, it is provided with a mesentery, the sigmoid mesocolon; the mesentery decreases in length from the center of the loop of colon toward either end, where it disappears, leaving the sigmoid colon fixed beneath the parietal peritoneum above and below (Figs. 572, 573).

The *rectum* (Fig. 617) extends from the termination of the sigmoid colon, opposite the middle of the third piece of the sacrum, to a point 5 cm. below the tip of the coccyx, where it becomes the anal canal (anal part of the rectum); its length is about 15 cm. It is curved with the concavity forward, being adapted in shape to the anterior surfaces of the sacrum and coccyx (Fig. 616). In addition to the sagittal curve, it likewise exhibits several lateral bends; at each such bend, usually two on the left and one on the right, the wall of the tube is inflected into the cavity as a crescentic, shelf-like fold; these internal rectal folds (transverse rectal folds, rectal valves, valves of Houston, valves of Kohlrausch) correspond to the creases, seen externally, which mark off the lateral curves. Beyond the coccyx the rectum is supported by the pelvic diaphragm, which it pierces in becoming continuous with the anal canal; in so doing it passes through the levator ani muscles (Fig. 617). Only the upper two thirds of the rectum have a partial peritoneal investment; the lower third is enveloped by loose connective tissue.

The *anal canal* begins at the level of the levator ani muscles where, for a short distance, it is situated in the thickness of the pelvic floor; here it departs from the vagina (Fig. 616), is directed backward, and makes a sharp angle with the rectum which brings it to the surface at the anal orifice (anus) about 3 cm behind the vaginal orifice. In passing through the pelvic diaphragm it is surrounded not only by the levator ani muscles, but also by the two anal sphincters; the internal one represents a considerable thickening of the circular musculature of the anal wall, while the external sphincter is a muscular collar situated on the external surface of the pelvic diaphragm in the fatty tissue of the ischiorectal fossae (Fig. 617).

Urinary Bladder

LOCATION, FORM AND RELATIONS. The urinary bladder is situated in the anterior part of the pelvic cavity, behind the bodies of the pubic bones, and in front of the vagina; it rests upon the funnel-shaped pelvic diaphragm (Figs. 615, 616). By these structures the organ is molded to the form of a three-sided pyramid. The larger end, the base or fundus of the bladder, rests against the anterior wall of the vagina; the smaller end, the apex or vertex,

bladder or the rectum; as the bladder fills, the organ is displaced backward and upward, and the degree of anteversion is decreased; on the other hand, in distention of the rectum, the uterus is carried forward, and anteflexion may become sharper. The uterus is said rarely to occupy an exactly median position; it is usually not only bent a little to one side or the other, but also slightly rotated upon its own long axis.

INTERIOR OF THE UTERUS. The *cavity of the uterus* is small in comparison with the size of the organ, because of the thickness of its walls. In sagittal section the cavity of the corpus is merely an elongated, narrow cleft between bulky, muscular walls that are almost in contact with each other (Fig. 616); in transverse section its outline is a flattened ellipse; when viewed in frontal section (Figs. 614, *A*; 699), it has the form of a triangle, all sides of which are convex inward. The base of the triangle is directed upward, and its two upper corners go over, as small funnel-shaped orifices, into the uterine tubes. The apex of the triangle is directed downward, where, at a constricted aperture, the internal orifice (internal os), corresponding to the isthmus externally, it becomes continuous with the cervical canal. The canal of the cervix is spindle-shaped and compressed somewhat anteroposteriorly, so as to have an oval outline in transverse section. The canal opens below into the vagina at the external orifice, at the tip of the vaginal portion of the cervix. Its mucous membrane, on the anterior and posterior walls, is raised into a series of palmate folds; the series consists, on each wall, of a longitudinal fold from which numerous secondary folds are sent off obliquely lateralward and upward—the similarity to the branchings of a tree suggesting the older term, *arbor vitae uterina*.

SUPPORTS OF THE UTERUS. The attachments of the uterus consist of two pairs of ligaments which, because of their shape, are termed the broad and the round (Fig. 614).

Each *broad ligament* is a double layer of peritoneum prolonged from the lateral margin of the uterus to the wall of the pelvis (Figs. 614, *A*; 618). The plane of the medial end is dependent upon the position of the uterus; when the latter is normally placed (Fig. 615), the anterior surface looks downward and forward, and the posterior surface upward and backward; at the attachment to the pelvic wall the plane is more nearly vertical. When retracted (Fig. 614, *A*), their form is observed to be that of quadrangular, winglike folds which jointly form a septum across the pelvis, dividing the cavity into an anterior portion containing the bladder, and a posterior housing the rectum. The upper free border of each ligament is then approximately horizontal. The upper border is the longest of the four; its inner four fifths are occupied by the uterine tube; the short lateral part extends beyond the tube, from the fimbriated end to the pelvic wall, as the suspensory ligament for the ovary (Fig. 699). The other three borders—medial, lateral and inferior—are fixed. The medial border is attached to the side of the uterus, where the layers of peritoneum diverge to surround the organ. The short lateral border is attached to the lateral wall of the pelvis just in front of the hypogastric artery. The inferior border, or base, of the ligament is rounded; sloping downward and inward, it follows the plane of the pelvic floor to which it is fastened, and ends medially on the upper portion of the vagina. At their lines of attachment to the pelvic wall and floor the two layers of the broad ligament pass in opposite directions, becoming continuous with the general peritoneal lining of the pelvic cavity. Along the inferior attachment the divergence of the layers leaves a nonperitoneal interval, through which the ureter passes diagonally forward and medialward, and across which the vessels and nerves reach the sides of the vagina and the uterus.

The two layers of peritoneum which form the broad ligament enclose the extraperitoneal connective tissue which, as it reaches the uterus, is termed the parametrium. Between the two serous layers are also contained the following structures: the uterine tube; the paroophoron and epoophoron; fibers from the superficial layer of the uterine musculature; visceral branches of nervous and vascular systems.

Two secondary folds originate from the broad ligament, one from each surface: from the posterior extends a fold, the mesovarium, containing the ovary and the ovarian ligament (Fig. 614, *A* to *C*); from the anterior passes a less prominent fold which contains the round ligament of the uterus (Fig. 615). The part of the broad ligament situated below the origin of the mesovarium is called the mesometrium; the narrower portion above, between the ovary

continued into that of the vagina in the middle line below (Fig. 614). The ova discharged from the ovaries find their way into the infundibula of the uterine tubes, through which they pass to the uterus. Should fertilization occur, the ovum becomes implanted there and undergoes prenatal development.

The uterus in the virgin is pear-shaped and somewhat flattened from before backward. The measurements are as follows: length, 7.5 cm.; width, 5 cm.; thickness, 3 cm. The uterus is divisible into three portions: a base or fundus; the main portion, termed the body or corpus; and the smaller, lower extremity, the neck or cervix, which projects into the vagina. The cervix is marked off from the corpus by a slight constriction, the isthmus (Fig. 614, *A*).

The *fundus* is that part of the dome-shaped, uppermost end of the organ which lies above a transverse line drawn between the points of entrance of the uterine tubes; it is broad in its transverse diameter, and convex in all directions (Fig. 614). At the junction with the fundus the uterine tubes leave the lateral margins as the so-called horns or cornua. The corpus narrows as it approaches the cervix and has then a somewhat triangular outline when seen from the front or the side.

The *body* (with the fundus) possesses two surfaces, an anterior and a posterior, and two margins, right and left. The anterior (also referred to as ventral or inferior) looks downward and forward, resting upon the bladder (Figs. 615, 616), and hence is appropriately termed vesical; it is slightly concave in nulliparae, and covered by visceral peritoneum, which, at the junction of the body and the cervix, is reflected to the upper aspect of the bladder, the vesicouterine excavation lying in the interval. The posterior (dorsal or superior) surface is in contact with the mesenterial portion of the digestive tube and hence is also termed intestinal. It is convex; the peritoneum extends downward beyond the body to invest the cervix, from which it is carried over to the front of the rectum. The space thus enclosed is the rectouterine excavation (Fig. 617). Each lateral margin of the uterus extends from the origin of the uterine tube to the pelvic floor; it is devoid of peritoneum, since it gives attachment to the diverging layers of the broad ligament (Fig. 614, *A*). The round ligament of the uterus arises at a point just in front of origin of the uterine tube, and the uterine and ovarian vessels are situated below and behind it; all these structures lie between the apposed layers of the broad ligament as it extends toward the wall of the lesser pelvis.

The *cervix* is the narrower, cylindrical segment of the uterus. It is continuous above with the inferior end of the corpus at the constricted isthmus; below, its tapering extremity projects into the upper end of the vagina (Fig. 617). The cervix is thus divided by its relation to the surrounding vaginal wall into two segments: an upper, supravaginal portion above the ring of attachment, and a lower, free segment or vaginal portion which projects into the vault of the vagina. The cervix enters the vagina through the upper part of its anterior wall in such a manner that the external orifice of the cervix is directed downward and backward to rest against the posterior vaginal wall; the latter ascends to a higher cervical level than does the anterior wall—even to envelop fully the inferior third of the cervix. The free projecting surface of the vaginal (or infravaginal) portion of the cervix is a convex prominence, transversely elliptical, with two rounded, prominent lips enclosing a transverse opening. The anterior of the two lips is lower, more rounded and less projecting; the posterior is thinner and longer. The aperture which they surround is the external mouth of the womb. In the virgin the orifice is a relatively small oval opening, but, after childbirth, it becomes a wider slit, with an irregularly nodular margin.

The cervix is covered on its posterior surface by peritoneum; however, on the anterior and lateral surfaces it is in contact with extraperitoneal connective tissue; these surfaces are related, respectively, to the bladder and the broad ligaments (Fig. 617).

In the virgin the uterus lies with its long axis parallel to that of the superior aperture of the pelvis minor, and almost at a right angle with the long axis of the vagina (an axis which corresponds to that of the inferior aperture of the pelvis). The fundus of the uterus is directed forward. As a consequence, the surface which might be regarded as anterior is actually brought downward to rest upon the bladder—a position described as one of anteversion; moreover, the organ is bent forward upon itself, being concave on its vesical or anterior surface, into a position of anteflexion.

Positions. Anteflexion and anteversion may be diminished or increased by distention of the

against the upper part of the vagina, while below the level of the bladder the urethra indents the anterior vaginal wall to produce the kneelike urethral *carina*. The fibrous tissue between the vagina and the bladder is loosely areolar; that which connects the vagina to the urethra is denser. These fibrous areas are frequently termed the vesicovaginal and the urethrovaginal septum, respectively; actually, they not only are continuous with each other; but also blend with the coats of the organs, the surrounding extraperitoneal tissue, and the pelvic fascia. Posteriorly, the upper segment of the vagina (behind the posterior fornix) is related to the rectouterine excavation of the peritoneum; in the middle two fourths the vagina lies in close apposition with the rectum, the contents of the latter viscus being easily palpable through the vaginal wall (Fig. 617). Here the two organs are connected by a fibrous extension of the pelvic fascia, termed the rectovaginal septum. In its lower fourth the vagina diverges from the rectum, and at the beginning of the anal canal they are separated by the perineal body (p. 735). Laterally, and above the level of the pelvic floor, the vagina is related to the vaginal branches of the uterine artery, the vesicovaginal plexus of veins and the terminal part of the ureter (as the latter duct passes forward and inward near the lateral fornix to reach the base of the bladder). All these structures are embedded in the loose extraperitoneal connective tissue. At the junction of its lower and middle thirds the vagina is enclosed by the levator ani muscles and the two investing layers of diaphragmatic pelvic fascia, through the anterior cleft in which it leaves the pelvic cavity (Fig. 620); the vagina next traverses the urogenital diaphragm (Fig. 617) from whose musculature and fasciae it obtains additional support; it finally passes through the superficial perineal compartment (Fig. 695), where on either side it is related to the bulb of the vestibule and the bulbocavernosus (*sphincter vaginae*) muscle (Fig. 694), and ends by opening upon the roof of the vestibule (Fig. 699).

Uterine Tubes

Form and Course. The *uterine tubes* (fallopian tubes) are the paired muscular canals about 12 cm. in length which extend from the uterus to the ovaries; they are covered by peritoneum and lined with mucous membrane. They may be regarded as the excretory ducts of the ovaries, inasmuch as they convey the discharged ova to the cavity of the uterus. They differ, however, from all other ducts in the human body in that the relation of gland to duct is one of apposition merely, and not one of continuity. The uterine tubes or oviducts, except for a short intramural course, are enclosed in the free margin of the broad ligaments; they occupy the upper division of the ligament which is known as the mesosalpinx (Fig. 614, *A*).

Traced from its proximal end (Figs. 614, *A*; 699), each tube emerges from the wall of the uterus at the junction of the corpus and fundus of the uterus. At first the tube courses horizontally outward and backward along the uterine or lower extremity (pole) of the ovary; it next ascends the pelvic wall, often in a tortuous fashion, along the mesovarial border of the ovary to the tubal or upper extremity, over which it arches backward; the tube finally descends upon the free border of the ovary, where its fimbriated end lies in relation with the medial surface of the ovary.

Divisions. The uterine tube presents four chief subdivisions (Figs. 614, *A*; 615): a short uterine portion; a slender isthmus, corresponding to the inner third of the tube; an ampulla, or dilated outer two thirds; a distally placed fringed and funnel-shaped infundibulum. The uterine part begins at the upper angle of the uterine cavity, with which it communicates by a minute orifice (*ostium*); the tube then traverses the muscular wall, appearing externally at the cornu, just above the uterine attachments of the round and the ovarian ligaments. The isthmus is the straight, cordlike portion which immediately adjoins the uterus; it is thick-walled and relatively narrow. The lumen of the isthmus gradually increases in diameter as it passes outward to join the ampulla, which is thin-walled and dilatable. The ampulla is the widest and longest subdivision of the tube, and is usually somewhat convoluted. This flexuous portion leads into the trumpet-shape expansion of the ovarian end of the tube, termed the infundibulum, the inner surface of which is thrown into folds continuous with those of the ampulla. The folds are prolonged to the end of the tube, where they project in the form of long, irregular processes, the *fimbriae*, which gives to the free margin a fringed or ragged appearance (Fig. 699). One fold, longer than the others, stretches toward the ovary and often attains

and the uterine tube, is the mesosalpinx (Fig. 614, *A*).

The *round ligaments* are not duplications of the peritoneal lining of the pelvis; they are true ligamentous bands. They represent the lower part of the gubernacula, which in embryos of both sexes descend through the abdominal parietes to the inner surface of the labioscrotal swellings. They are enclosed between the serous layers of the broad ligaments, and attached medially to the upper angles of the uterus in front of and below the uterine tubes (Fig. 615). Each round ligament is composed principally of smooth muscle fibers prolonged from the uterus, together with a certain amount of connective tissue and some small vessels and nerves. Occasionally in the adult the ligament is accompanied by a persistent tubular prolongation of the abdominal peritoneum, the canal of Nuck (processus vaginalis peritonaei), which in exceptional cases may extend with the ligament into the labium. The round ligament runs first in a rather horizontal plane (Fig. 615), extending outward and forward from its attachment to the anterolateral portion of the uterus to the side wall of the lesser pelvis. In this first part of its course the cord lies between the layers of the broad ligament, the anterior one of which it elevates into a low fold; it then passes in a forward and slightly upward direction (Fig. 619), under the peritoneum, crossing the obliterated hypogastric artery, the external iliac vessels, and the psoas major muscle; having thus ascended the lateral wall of the lesser pelvis, it crosses the pelvic brim and turns lateralward to attain the abdominal inguinal ring, through which it leaves the abdomen to traverse the inguinal canal. In passage through the canal the ligament is covered by investments derived from the parietal abdominal layers through which it passes. Upon emerging through the subcutaneous inguinal ring the ligament occupies a digitiform process whose outermost coat is the superficial fascia (Frontispiece, Part VI).

Vagina

Form and Course. The *vagina* is the flattened but distensible muscular and membranous canal which extends from the cervix of the uterus above to the external genitals below (Fig. 616). The course of the vagina is downward and forward in a direction generally parallel with the plane of the superior aperture of the pelvis minor. The long axis of the vagina forms, with that of the anteverted uterus, an angle of about 90 degrees open toward the pubic symphysis; consequently the uterus has the appearance of becoming continuous with the vagina by piercing the latter's anterior wall (Fig. 617). The portion of the obliquely placed cervix, which thus lies within the upper end of the vaginal canal, ends in two freely projecting labia: a short anterior, and a longer posterior one. As the vagina expands to embrace the labia, a narrow, annular groove, the fornix, is formed between the vaginal wall and cervical lips, which for convenience is often regarded as consisting of an anterior, a posterior and two lateral fornices. Since the vagina, in becoming united to the cervix, rises higher upon the posterior than upon the anterior lip, the posterior fornix is the deeper of the two, and the corresponding vaginal wall is longer (8 cm. as compared with 6.5 cm.). In the middle portion of its course the anterior and posterior walls are in contact, and the contained cavity is reduced to a transverse slit (Fig. 617). In the lower portion the cavity is invaded by prominent median elevations or columns (*columnae rugarum*) from the anterior wall and on the posterior wall in such a manner that the lumen, as seen in transverse section, is modelled to the form of a letter H with long crossbar and shorter lateral limbs convex medialward (Fig. 614, *E*). The lower portion of the anterior column is especially pronounced, owing to the bulging produced by the adjacent urethra; here the column is raised to form the urethral carina—a crestlike elevation situated just dorsal to the external urethral orifice. From each side of the longitudinal *columnae*, in nulliparae, numerous transverse ridges (*rugae*) extend obliquely outward, lending a corrugated appearance to the surface of the lining membrane. The transverse rugae are particularly conspicuous on the anterior wall; in general they fade away as the lateral walls are approached. The breadth of the vaginal canal decreases from above downward; it opens below to the exterior through the vaginal orifice, which communicates directly in the vestibular space enclosed by the labia minora (Fig. 693). The size and shape of the orifice are dependent upon the condition of the hymen.

Relations. The vagina is intimately related anteriorly to the urinary bladder and the urethra (Fig. 616); the fundus of the bladder rests

sent the embryonic gubernaculum of the ovary, the entire cord being subdivided into ovarian and uterine portions.

Each suspensory ligament (*infundibulopelvic ligament*) extends from the tubal extremity of the ovary to the lateral wall of the pelvis; it is the lateral fifth of the broad ligament, that is, the part not occupied by the uterine tube. Structurally, the ligament is a fan-shaped band of fibrous and muscular tissue over which the peritoneum is elevated into a fold of triangular shape (Fig. 618). It passes upward from the ovary, crossing the external iliac vessels, to become lost in the fascia and peritoneum covering the psoas major muscle. The tissue in the ligament forms a bed for the ovarian vessels and nerves as they enter the pelvis minor on the way to the broad ligament and the ovary.

Vessels and Nerves

The major portion of the course of all the vessels supplying structures within the pelvis lies in the extraperitoneal fatty tissue which intervenes between the peritoneum and the fascia covering the deep surface of the musculature (Fig. 619). The nerves, on the contrary, lie at first outside the fascia; they are not only retroperitoneal, as are the vessels (and viscera) but also "retrofascial" (as are the muscles) (Fig. 620). Therefore the visceral branches of the vessels pierce the fascia once—in penetrating the reflection of it which is carried upward from the pelvic organs; the parietal branches likewise pierce it but once, as they pass from the pelvis to the perineum, carrying prolongations of the fascia which blend with their adventitial coats. The nerves which supply the organs must pierce the fascia twice: once as they emerge from the bony foramina or leave the ganglia of the sympathetic chain, and again as they enter the substance of an organ; in leaving the pelvis, those destined for the perineum do not pierce the fascia because they already lie external to it.

With the exception of the ovarian, the sigmoidal and the superior mesenteric arteries, the vessels which supply the pelvic organs and parietes arise within the pelvis minor from the hypogastric division of the common iliac. The corresponding veins follow comparable courses in leaving the organs. The ovarian arteries, however, arise from the aorta at the level of the kidneys, and the ovarian veins enter the inferior vena cava on the right side, the renal vein on the left. In general, the major lymphatic drainage follows that of the veins, into groups of pelvic lymph nodes associated with the large arteries and named accordingly (Fig. 621). The ovarian drainage is principally into glands along the aorta. The perineum and the pelvic parietes receive their innervation mainly from sacral nerves; but the pelvic viscera are supplied not only by nerves of sacral origin, but also by thoracolumbar sympathetic branches (*cf.* Figs. 569, 570, pp. 586, 588).

ARTERIES. The hypogastric arteries are the principal vessels supplying blood to the walls and the viscera of the pelvis, the external organs of generation in the perineum, and the musculature of the buttocks and of the medial side of the thighs (Figs. 619, 620). Each hypogastric (internal iliac) artery is the medial terminal branch of the corresponding common iliac; it arises at the bifurcation of the latter, opposite the lumbosacral articulation. The artery passes downward and backward in the pelvis for a distance of about 4 cm., crossing the psoas major and the piriformis muscles and then the lumbosacral trunk of nerves. Typically, the artery ends in the pelvis minor by dividing into two large trunks, termed posterior and anterior divisions, opposite the upper margin of the greater sciatic foramen. The posterior division is the usual stem of origin of the following parietal branches: iliolumbar, lateral sacral, and superior gluteal. The anterior division gives rise to both parietal and visceral branches, of which the inferior gluteal, obturator and internal pudendal are parietal; and the superior vesical, middle vesical, middle hemorrhoidal, uterine and vaginal are visceral branches. All the visceral branches and the internal pudendal artery call for further discussion.

The superior vesical arteries are slender vessels, one to three in number on each half of the pelvis. They arise from the anterior division of the hypogastric, the main stems dividing into numerous branches upon nearing the bladder, supplying mainly the superior and inferolateral surfaces (Fig. 619). The lowest of the superior vesical arteries, distributed to the posterior surface of the viscus, is frequently termed the middle vesical. The superior vesical artery of the adult represents the proximal portion of the umbilical artery of the fetus.

In the fetus the umbilical artery constitutes the main stem of the hypogastric, and is twice

the tubal pole; this ovarian fimbria is attached throughout its length to the mesosalpinx of the broad ligament. The uterine tube communicates directly with the peritoneal cavity by a small aperture, the abdominal ostium, situated in the depths of the infundibulum.

Ovaries

FORM, SIZE AND STRUCTURE. The genital glands of the female are homologous with the testes in the male. They are solid, nodular bodies, with the proportions of a large unshelled almond, situated on either side of the uterus, behind and below the uterine tubes (Fig. 614, *A*, *B*). They are attached to the back of the broad ligament and to the lateral wall of the lesser pelvis by peritoneal folds (Fig. 614, *A*). The ovaries contain numerous ova, which are discharged during ovulation by the periodic rupture of the follicles; in addition to being cytogenic glands, the ovaries produce hormones regulatory of the development and activity of the female reproductive organs. The ovaries show considerable individual variation in size, and the right is commonly somewhat larger than the left. The average dimensions are 3.6 cm. in length, 1.8 cm. in breadth, and 1.2 cm. in thickness. Each ovary possesses two extremities and two surfaces—the latter separated by borders along one of which the hilum is situated.

POSITION AND RELATIONS. When the body is in the erect posture, the normally placed gland rests against the inner aspect of the pelvis, with the long axis (connecting the two extremities) in the vertical plane, and its greater diameter (connecting the two margins) in parasagittal plane. The tubal extremity, or upper pole, of the organ is rounded, directed superiorly and embraced by the uterine tube; it is attached to the peritoneum of the pelvic wall above by the suspensory ligament, and usually also to the ovarian fimbria of the uterine tube (Fig. 642). It reaches upward almost to the level of the external iliac vein and the pelvic brim, to be overhung by the medial edge of the psoas major muscle. The uterine extremity, or lower pole, is narrow and pointed, and directed inferiorly; it is fastened to the adjacent lateral margin of the uterus by the ligament of the ovary (Figs. 615, 618). The lower pole extends downward almost to the level of the pelvic floor, to a point just above the upper border of the piriformis muscle and the ischiadic (sciatic) nerve. The medial surface is directed inward, but since it is to a great extent covered by the uterine tube, only a relatively small part of it is exposed free to the pelvic cavity and to the contained portions of the intestines. The lateral surface faces outward and is in direct contact with the parietal peritoneum of the pelvis, where this layer is depressed to form a shallow fossa (*fossa ovarii*) of triangular outline, in the angle between the diverging external iliac and hypogastric vessels. The lateral umbilical ligament (obliterated hypogastric or umbilical artery) in front, and the ureter and the uterine artery behind, form the immediate boundaries of the recess as they lie in the extraperitoneal fatty tissue. The obturator vessels and nerve, coursing obliquely across the obturator internus muscle, intervene between the peritoneum of the fossa and the bony wall of the pelvis. Below, the boundary of the fossa is indistinct, fading insensibly into the pelvic floor. Two margins connect the surfaces. The posterior margin or border is free, thick and rounded; it is directed backward and slightly inward toward the ureter. The anterior margin is narrower and straighter than the posterior; it is directed forward and somewhat outward toward the obliterated umbilical artery. This border presents an oblong groove or hilum, and is attached by a short peritoneal fold (*mesovarium*) to the back of the broad ligament of the uterus (Fig. 614, *A*); between the approximated layers of the mesovarium the vessels and nerves reach the hilum.

SUPPORTS OF THE OVARY. In addition to the mesovarium, by which the ovary is attached to the posterior surface of the broad ligament, the organ possesses two other supporting structures, namely, the ovarian and the suspensory ligaments. Each ovarian ligament (utero-ovarian ligament) is a rounded cord, consisting of connective tissue and smooth muscle, which lies enclosed between the layers of the broad ligament (where it may be seen through the peritoneum as it courses along the line separating the mesosalpinx from the mesovarium). The ligament extends from the uterine or lower extremity of the ovary to the lateral aspect of the uterus, where it is attached between the uterine tube and the round ligament of the uterus. The ligament of the ovary and the round ligament of the uterus together repre-

a similar origin and relation in the abdominal part of their course; but since they do not leave the pelvis, they are shorter than the corresponding vessels to the testes. Each artery arises from the front of the aorta, slightly below the point of origin of the renal arteries, opposite the second lumbar vertebra. The artery courses obliquely downward and lateralward, upon the psoas major muscle and behind the parietal peritoneum, crossing the external iliac vessels and the ureter, and entering the lesser pelvis (Figs. 617, 619). Here their route is through the suspensory ligament of the ovary (Fig. 618). They next pass between the layers of the broad ligament, below the level of the uterine tube, inward toward the ovary, which they attain by coursing backward in the mesovarium. The vessels divide into terminal branches which enter the hilum of the ovary, forming broad anastomoses with the ovarian rami of the uterine artery.

The internal pudendal artery is one of the dorsal branches of the anterior division of the hypogastric artery. Each arises on the side of the piriformis muscle, below the inferior margin of which it leaves the pelvis minor through the lower part of the greater sciatic (ischiadic) foramen; therefrom it winds over the ischial spine, covered by the gluteal muscles, and enters the ischiorectal fossa through the lesser sciatic foramen (Figs. 623, 624). In the ischiorectal fossa the artery is accompanied by *venae comites* and by the pudendal nerve. In this situation the artery lies in a fibrous canal (of Alcock), formed by the fascia covering the obturator internus muscle (Fig. 694). In the fossa the artery of each side gives off a branch, the inferior hemorrhoidal artery, which, after piercing the wall of the canal, passes medialward through the fatty tissue of the fossa, giving numerous twigs to the anus and the anal canal. The vessel also supplies the superficial fascia and integument of the perineum, and the skin and musculature of the gluteal region.

Upon reaching the base of the urogenital diaphragm, at the line of division between the two portions of the perineum, the branches of the internal pudendal artery enter the urogenital part of the perineum by three routes: through the superficial fatty tissue just beneath the integument; through the superficial perineal compartment, on the way to the structures situated therein (Fig. 694); and through the deep perineal compartment (Fig. 696). The first route is followed by small branches of the internal pudendal, belonging to the posterior labial group, which are distributed to the skin and fatty tissue of the labia. The second route is the one followed by the perineal artery of each side. This vessel enters the superficial perineal pouch by passing either over or under the superficial transverse perineal muscles (Fig. 694). Within the compartment its course is forward, parallel to the pubic arch, in the triangular space enclosed by the ischiocavernosus, bulbocavernosus and transverse perineal muscles, all of which it supplies. The third route is that followed by the clitoridal artery, which, on leaving the perineal artery, enters the deep compartment by piercing the base of the urogenital diaphragm (Fig. 695); within the compartment it continues forward along the inferior ramus of the pubis in the substance of the urethral sphincter muscle, giving off the bulbar and the urethral arteries, and ending in the terminal branches, the deep and the dorsal arteries of the clitoris.

Thus the four branches are distributed chiefly to the erectile tissue in the superficial perineal compartment, which they reach by piercing the inferior fascia of the urogenital diaphragm. The first branch, the artery to bulb, is a short, thick vessel which usually arises just as the clitoridal artery enters the deep compartment; occasionally it takes origin from a common stem with the dorsal artery. The artery passes medialward toward the urethra and, before reaching the midline, penetrates the inferior fascial layer to enter the cavernous tissue of the vestibular bulb (Fig. 695). The urethral artery takes origin anterior to the bulbar, but otherwise is similar to it in course and distribution. The deep artery of the clitoris, in passing through the fascial floor of the deep compartment, lies just medial to the corpus cavernosum clitoridis, which it pierces obliquely. The dorsal artery of the clitoris courses forward between the fascial layers of the diaphragm to a point just behind the transverse pelvic ligament (Fig. 696). There it passes through the inferior fascial layer and extends outward upon the dorsum of the clitoris, finally turning backward again to send branches into the glans; the vessels communicate through the pars intermedia with those from the bulbar artery.

Veins. The tributaries of the hypogastric vein correspond with the branches of the hypo-

as large as the external iliac. It passes along the lateral pelvic wall, toward the apex of the bladder, whence it ascends to the umbilicus on the posterior surface of the anterior abdominal wall on either side of the allantoic duct (urachus), enclosed between the peritoneum and the transversalis fascia. It is joined by the artery of the opposite side and by the umbilical vein, and passes through the umbilical cord to the placenta. When at birth the cord is tied and cut, the portion of each artery between the umbilicus and the bladder collapses, becoming converted into an impervious fibrous cord, the lateral umbilical ligament (obliterated hypogastric artery). The proximal portion, between the bladder and the hypogastric artery, remains patent, and from it arise the one or more superior and middle vesical arteries.

The fibrous lateral umbilical ligament, the middle umbilical ligament (Fig. 619), and the inferior epigastric artery elevate the overlying peritoneum in such a way as to produce three folds on the anterior abdominal wall: one medial and two lateral. These peritoneal folds mark off three fossae of topographical importance on either side of the middle line above the level of the bladder and of the inguinal ligament: the supravesical fossa, between the middle and lateral umbilical folds; the medial inguinal fovea, between the lateral umbilical and the epigastric folds; and the lateral inguinal fovea to the outer side of the epigastric fold (Fig. 367).

The vaginal artery represents the inferior vesical artery of the male. It passes downward and medialward from its hypogastric origin, to supply the vagina, and also sends small twigs to the lower aspect and the fundus of the bladder (Fig. 619).

The uterine artery of each side originates from the anterior division of the hypogastric artery. The vessel lies first on the inner wall of the lesser pelvis, passing medialward and slightly forward on the fascia covering the upper surface of the levator ani muscle, to the lower margin of the broad ligament. In the parametrial tissue, enclosed by the peritoneal layers of the ligament, it arches over the ureter about 2 cm. from the uterus. Upon reaching the cervix of the uterus, at a point just above the lateral fornix of the vagina, it gives off a vaginal branch, which courses downward on the lateral vaginal wall. The main vessel follows a tortuous course upward, along the lateral margin of the uterus between the layers of the broad ligament (Fig. 699). The artery ascends as far as the fundus, giving off many spiral branches to the anterior and the posterior surfaces of the organ. These vessels anastomose not only with one another, but also freely with those of the opposite side. The uterine artery continues as a laterally directed stem, which divides into branches supplying the ovary and the uterine tube; the ovarian ramus passes along the mesovarial border of the ovary, anastomosing with the ovarian artery; the tubal ramus runs outward within the mesosalpinx, along the course of the uterine tube.

The middle hemorrhoidal artery usually arises from the anterior division of the hypogastric (Fig. 619); it runs inward and then downward along the lateral surface of the middle portion of the rectum, supplying the viscus, and anastomosing with the superior hemorrhoidal artery from the inferior mesenteric, and with the inferior hemorrhoidal branch of the internal pudendal artery.

The sigmoid and superior hemorrhoidal arteries are derived from the inferior mesenteric branch of the abdominal aorta.

The sigmoid arteries, usually two or three in number, arise from the convexity of the inferior mesenteric (Fig. 515); coursing downward and to the left, they cross the left iliac and psoas major muscles beneath the parietal peritoneum, and enter the root of the sigmoid mesocolon; between its layers they give off ascending and descending branches which, by a series of arches, anastomose with the left colic artery and the superior hemorrhoidal artery, respectively.

The superior hemorrhoidal artery is the continuation of the main trunk of the inferior mesenteric. It descends into the pelvis minor between the layers of the sigmoid colon to the dorsum of the rectum. At the junction of the sigmoid colon and the rectum, opposite the third segment of the sacrum, the artery divides into two branches which pass from the back to the sides of the rectum; there the branches break up into several finer stems, which form a series of loops around the organ and communicate with the middle hemorrhoidal branches of the hypogastric and the inferior hemorrhoidal branches of the internal pudendal.

The ovarian arteries are homologous to the internal spermatic arteries in the male, having

adjacent group, the superficial glands, arranged in a chain of ten to twenty just below the inguinal ligament, likewise receive perineal vessels, which include those from the anus and from the pudendum (vulva); into this group also pass the afferent lymphatics of the abdominal wall below the level of the umbilicus.

The efferent vessels from both groups converge toward the large, oval-shaped aperture (fossa ovalis; saphenous opening) in the deep fascia of the thigh (fascia lata femoris), through which they pass to gain the deep subinguinal glands, situated on the medial side of the femoral vein, and numbering usually not more than three. The deep glands also receive the afferent vessels from the clitoris and associated structures. The highest one of these glands (node of Cloquet; of Rosenmüller) is situated in the femoral ring. The group as a whole is continuous with an extensive chain of parietal pelvic glands grouped in relation to the common iliac artery (Fig. 593), with its two branches, and accordingly named the external iliac, the hypogastric and the common iliac glands —all of which are connected by numerous anastomoses (Fig. 621). The pelvic glands send their efferent vessels upward to a large group of intercommunicating lumbar glands, which, because of their positions in relation to the abdominal aorta, are called preaortic, retroaortic and lateral aortic glands; the efferents of the aortic glands end in the cysterna chyli of the thoracic duct, usually at a point opposite the second lumbar vertebra (Fig. 204, p. 216).

The lymphatic vessels from the pelvic organs terminate chiefly in the hypogastric and the iliac glands; a smaller number end in the aortic, relatively few in the inguinal glands (Fig. 621). Those from the bladder pass to the external iliac, the hypogastric and the common iliac glands; those from the urethra and the intrapelvic part of the ureter, to the hypogastric glands. The efferent vessels from the cervix of the uterus and from the major portion of the vagina drain, as do those of the urinary bladder, into the three groups of pelvic glands; those from the lowermost part of the vagina, however, descend to join those of the pudendum and pass to the superficial inguinal glands. The majority of the vessels from the fundus and the cervix of the uterus pass lateralward in the broad ligament, and, becoming continuous with those of the ovary, ascend with the ovarian vessels to the aortic glands (Fig. 638); however, some pass to the hypogastric and both groups of iliac glands. The efferent vessels of the uterine tube join those of the uterus and of the ovary. The vessels from the rectum pass upward to glands in the sigmoid mesocolon, and thence to the aortic glands; those from the anal canal end in the hypogastric glands; and, as has been stated, the lymphatics from the anus pass forward with those of the perineum to the inguinal glands.

Surgical Considerations

Cellulitis of the Broad Ligament. The normal broad ligament is too soft to be felt in vaginal or rectal examination. When the broad ligament is infected, it becomes brawny and indurated. Circumscribed abscesses may be located and differentiated from generalized thickness in the ligament resulting from diffuse cellulitis. The cellular tissue within the ligament is exposed both to trauma and to infection, which may bring about a localized or diffuse cellulitis.

In the presence of infection, *traumatic cellulitis* may occur from pressure or tears during labor, or from use of a badly fitting pessary which injures the cellular tissue about the vaginal fornices (paracolpium). Thrombosis of the veins sometimes occurs, and the cellular tissue becomes edematous and swollen.

Septic cellulitis usually is caused by infection complicating labor or abortion, and sometimes is produced by intrauterine instrumentation or operation. Infected wounds after vaginal operations may give rise to septic cellulitis. In labor or abortion there often are lacerations extending more or less deeply into the cervix or through it into the parametrium. These lacerations afford an entrance for infective organisms which gain access to the cellular tissue directly or by way of the lymphatics or veins.

An exudate in the parametrial tissue either undergoes resolution and gradually becomes absorbed, or localizes, softens, and forms an abscess. The more virulent infections may exhibit no local manifestations, but may pass through the intermediate lymphatics of the broad ligament and enter the general circulation. Pus from an abscess, if not released by incision, may burrow along the wall of the vagina, bulge into the vaginal fornices, and rupture into the vagina or rectum. The abscess may be discharged into the bladder, into an

gastric artery, with the exception of the fetal umbilical vein, which is received not by the hypogastric vein, but by the liver. All the veins are associated with extensive venous plexuses (Figs. 617, 618), which immediately surround the pelvic organs, and communicate with one another more or less freely.

The internal pudendal veins are associated through the greater part of their course with the artery of the same name; however, they not only carry blood posteriorly through the perineum, but also communicate anteriorly with the veins which lie within the pelvis immediately behind the pubic symphysis (Fig. 617). The veins, which are usually double, in following the course of the pudendal artery on each side, begin with the deep veins of the clitoris which issue from the substance of the corpora cavernosa clitoridis; as they run dorsalward, they receive the bulbar, perineal and posterior labial veins in the urogenital triangle, and the inferior hemorrhoidal veins in the anal triangle; in the latter region they are enclosed in the canal of Alcock with the artery and the pudendal nerve. The veins leave the perineum through the lesser sciatic foramen and, after winding over the spine of the ischium, enter the pelvis through the greater notch (see corresponding artery, Figs. 623, 624); here they empty into the hypogastric vein.

The veins which course anteriorly receive as their chief tributary the dorsal vein of the clitoris, which is frequently double through part of the course. At the root of the clitoris the vein quits the dorsal surface of the organ and, perforating the fascia of the urogenital diaphragm (*cf.* Figs. 696 and 697), enters the pelvis through the small subpubic space enclosed by the pubic arcuate and transverse pelvic ligaments (Fig. 617); here it sends a branch to either side of the pudendal plexus. The latter network of veins is situated between the pelvic surface of the pubic symphysis and the urinary bladder. It drains into the hypogastric vein, but chiefly into the vesical plexus, which is lodged in the cellular tissue surrounding the inferior aspect of the bladder and is formed largely by veins received from that viscus. The vesical plexus communicates posteriorly with the uterovaginal plexus. The veins which return blood to this plexus lie in the walls of the uterus and the vagina. In the uterus they form a distinct layer in the muscular wall, termed the *stratum vasculare;* passing outward and downward on both surfaces of the uterus to the lateral margins, they converge toward the uterine vein on each side, forming a plexus between the layers of the broad ligament. In the walls of the vagina the veins pass outward and upward, likewise joining the vaginal vein; thus the two portions of the plexus, uterine and vaginal, are continuous at the level of the external uterine orifice. The uterine veins, paired on each side of the pelvis, open into the corresponding hypogastric vein and also communicate posteriorly with the hemorrhoidal plexus which surrounds the rectum. The plexus consists of two intercommunicating portions, an internal situated between the mucosal and muscular coats, and an external upon the outer surface of the latter. The lower part of the plexus, as already mentioned, drains into the internal pudendal vein in the ischiorectal fossa; the middle part, through the middle hemorrhoidal veins, opens into the hypogastric vein; the upper part, by the superior hemorrhoidal and sigmoidal veins, reaches the inferior mesenteric vein. Through the medium of the plexus, and its connections with the hypogastric and the inferior mesenteric veins, the systemic (inferior caval) and the portal systems are brought into communication with each other.

The ovarian veins issue from the hilus of the ovary and pass between the layers of the broad ligament; here they anastomose freely, forming an extensive network which corresponds to pampiniform plexus of the spermatic cord in the male. The veins are constituents of the suspensory ligament of the ovary (Figs. 617 to 619). The plexus communicates with the uterovaginal plexus, and also gives off two ovarian veins which, corresponding to the internal spermatic veins, accompany each ovarian artery. The two veins of each side finally fuse to form a single terminal vessel, which usually on the right side opens into the inferior vena cava, and on the left into the left renal vein.

LYMPHATIC VESSELS AND GLANDS. The afferent lymphatic vessels from the integument and subcutaneous tissue of the perineum (Fig. 621), together with the superficial afferent vessels from the lower extremity, are received by a group of lymph nodes situated on either side of the upper part of the great saphenous vein (internal or long saphenous vein), and termed the superficial subinguinal glands. An

midsagittal septum which later disappears, and the double uterine and vaginal canals become a single cavity.

The absorption of the median partition occurs from the vulva upward to the fundus of the uterus. According to the degree of septum absorption, there may be found a partitioned vagina with a partitioned uterus; a completely developed single-cavity vagina and a partitioned uterus; or a single vagina and a single uterus. An arrest in the development of the paramesonephric ducts explains the actual *absence of the uterus and vagina*. Rarely, the ducts remain separate throughout their length and form two entirely *separate uteri and vaginae*. Each of these cavities has the function of the normal organ. The body of the uterus may be cleft completely, the *bicornuate uterus*, and the cervix be single or divided (Fig. 625, 1 and 2). The duplexity of the uterus may be partial and

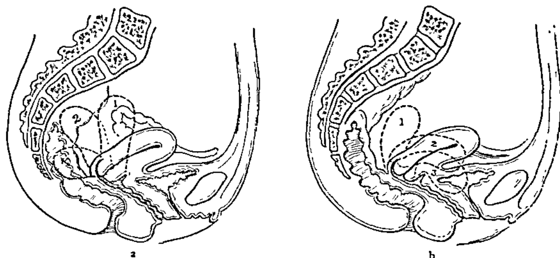


Fig. 626. TYPES AND DEGREES OF UTERINE DISPLACEMENT. SCHEMATIC.

a, Departures, dorsalward, from the normal position of anteversion, as shown in the solid lines: 1, retroversion; 2, moderate retroflexion; 3, marked retroflexion.

b, Departures, in additional ways, from the normal position of anteversion (indicated as in *a*): 1, retroversion; 2, moderate anteflexion; 3, marked anteflexion. (From Moorhead: Traumatic Surgery.)

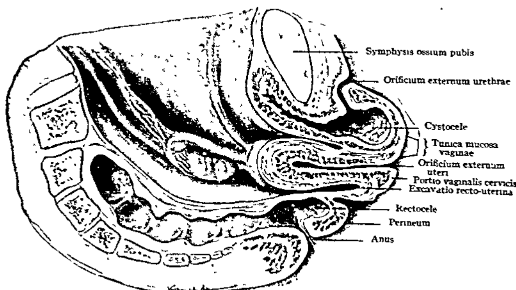


Fig 627. PARTIAL PROLAPSE OF THE UTERUS.

A cystocele and a rectocele accompany the prolapse; the *cervix projects through the vulva.*

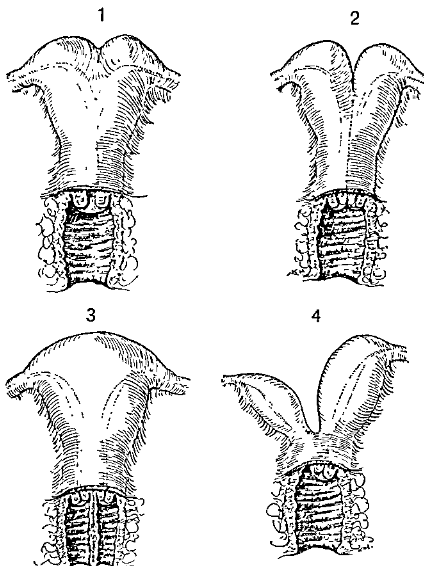


Fig. 625. VARIETIES OF MALFORMATION OF THE UTERUS.

1, Arched bicornuate uterus; 2, bicornuate bicervical; 3 and 4, biseptate uterus, in which one division is rudimentary, the other functional.

adherent loop of intestine or into the pelvic cavity. A large parauterine abscess may elevate the peritoneum, extend forward, and present behind the symphysis. It may burrow laterally and be accessible to evacuation by extraperitoneal inguinal incision. This method of evacuation may be used before a broad ligament abscess points in the inguinal region. Rarely, infection may diffuse outside the lateral pelvic peritoneum to present externally in the loin. Pus has been known to burrow through the pelvic floor and localize in the ischiorectal fossa.

Extraperitoneal pelvic cellulitis must be differentiated from intraperitoneal pelvic peritonitis. The palpable mass in extraperitoneal pelvic cellulitis is continuous with, and fixed to, the pelvic wall. In intraperitoneal pelvic peritonitis the mass usually occupies a position in the rectouterine cul-de-sac.

MALFORMATIONS OF THE UTERUS. Malformations of the uterus result from anomalies in the development of the müllerian (paramesonephric) ducts (Fig. 625). In the embryo each of the two ducts is a thick-walled tube with an independent cavity. In the course of development each duct is divided into a uterine tube, uterus and vagina; later the inferior extremities of the ducts become apposed and fuse in the median line. Fusion takes place over the parts which form the uterus and vagina. The upper or tubal parts retain their independence indefinitely as the two uterine tubes. The fused uterus and vagina at first are partitioned by a

variety of inversion a submucous fibroid of the polypoid type fills the cavity of the uterus until the cervix is partially distended. Contractile efforts to expel the growth as a foreign body lead to further dilatation of the cervix and dragging downward of the fundus by the weight and attachment of the tumor. The expulsive efforts and downward traction continue until the inversion or evagination becomes complete.

VAGINAL EXAMINATION OF THE UTERUS AND ADNEXA. *Examination of the external genitals* consists in noting the orifices of Bartholin's glands and examining any swellings or other evidences of infection. The condition of the hymen is noted, whether intact, dilated or torn. A puffy, red condition about the urethral orifice is evidence of inflammation (p. 746), and an attempt is made to express pus from the paraurethral gland by milking down the urethra through the anterior vaginal wall against the pubic arch. *Simple vaginal examination* may be done preliminary to bimanual examination. The labia majora are separated to expose the labia minora. The strength of the muscles surrounding the vaginal outlet is determined by making pressure against the posterior vaginal wall in the presence of voluntary contraction of the muscles of the perineum. The cervix is felt as a knoblike prominence in the vault of the vagina. Its axis may point backward toward the sacrum or forward toward the symphysis, according to the position of the uterus. A lacerated cervix, or one studded and infiltrated with follicles, or indurated with carcinoma, can be distinguished readily from the normal smooth cervix. If the uterus is in slight anteposition, the body cannot be felt with one hand alone; if acutely flexed, it can be felt as a resisting mass by tapping the anterior vaginal wall anterior to the cervix.

Bimanual examination consists in palpating the abdominal wall above the symphysis with one hand and palpating through the vagina with the other. The bladder should be empty at the time of examination. Pressure is made upon the abdomen to prevent upward displacement of the uterus and adnexa by the fingers in the vagina.

Bimanual palpation anterior and posterior to the cervix determines whether the body of the uterus lies in anteposition or retroposition (Figs. 629, 631). When the fundus lies anterior to the cervix, the vaginal finger palpates the body of the uterus through the anterior vaginal wall and transmits each movement to the abdominal hand. The ovary usually may be held and palpated by carrying the vaginal fingers far up into the lateral fornix of the vagina while deep pressure is made by the abdominal hand over the corresponding semilunar line. The

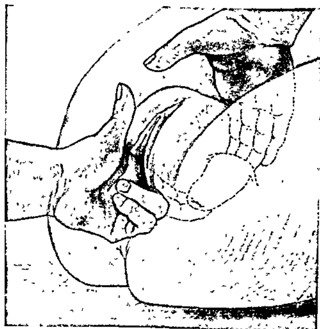


Fig. 629. METHOD OF BIMANUAL PALPATION OF THE UTERUS AND ADNEXA.

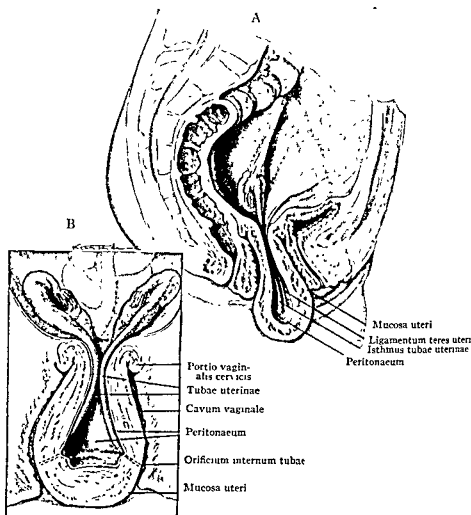


Fig. 628. INVERSION OF THE UTERUS.

A, Partial extravaginal inversion; *B*, intravaginal inversion.

limited to a branching fundus with a well formed partition in the body and cervix. The only evidence of duplexity may lie within the uterus where a more or less definite septum divides the uterine cavity (*uterus septus*, Fig. 625, 3 and 4). If one component of a paramesonephric duct fails to keep pace with the other in development, all varieties of asymmetry result, from suppression of a tube in a bicornuate uterus to simple unilateral deviation of the fundus. A localized stenosis or imperforation at any point in the uterine or vaginal canal is a serious developmental accident caused by incomplete resorption or defective cavity formation in the primitive paramesonephric duct. Stenosis may cause retention of menses proximal to the obstruction and form a tumor of considerable size, known as a *hematocolpos*, *hematocolpometra* or *hematometra*, according to whether the tumor occupies the vagina, the vagina and uterus, or the uterus alone (Fig. 647).

INVERSION OF THE UTERUS. Inversion of the uterus is an abnormal condition in which the organ is turned partially or completely inside out. The uterine mucosa becomes the covering of the inverted organ. In partial or *intrauterine inversion*, part of the uterus is invaginated into the uterine cavity without presenting through the cervix. In *intravaginal inversion*, part or all of the body of the uterus is evaginated through the external os into the vaginal canal (Fig. 628, *B*). In *extravaginal inversion* the evaginated uterus is partially or completely outside the vagina, and requires an evagination of the vagina (Fig. 628, *A*).

Inversion of the uterus is usually a complication of labor and may possibly be produced by traction on the cord in ill-advised attempts at delivery of the placenta. In the nonpuerperal

ovary is manipulated between the fingers until its surfaces and free border are examined thoroughly. The ovary normally is a freely movable firm body about the size of a large almond. Normally, the tubes cannot be felt, but when they are thickened by disease, their uterine ends may be rolled between the fingers and traced laterally toward the pelvic walls.

When there is obscure or deep-seated pelvic disease, bimanual vaginal examination combined with rectal examination (*abdominovaginorectal examination*) frequently is of great diagnostic value (Fig. 631).

Examination under general anesthesia may be of assistance in obscure intrapelvic disease. Ether or spinal anesthesia eliminates voluntary muscle resistance, completely relaxes the abdominal musculature, and prevents muscle resistance when tender areas are palpated. The examination can be conducted with a thoroughness impossible otherwise; the uterus may be pressed down, adhesions pulled upon, the perineum invaginated deeply, and the inflamed ovaries and tubes examined satisfactorily (Figs. 629 to 631). In indefinite pelvic conditions this examination should precede exploratory laparotomy.

HYSTERECTOMY. Hysterectomy, or removal of the uterus, may be partial or complete (Figs. 633 to 641). Partial hysterectomy may be done at any level above the vagina and is usually supracervical. Removal of the fundus alone is a fundectomy or supracervical defundation of the uterus. Complete removal of the uterus is panhysterectomy.

Partial hysterectomy has few advantages over total hysterectomy, except that it is an easier and safer procedure for the inexperienced surgeon. The usual contention is that the remaining cervix leaves a normal vaginal tract and supports the vaginal vault. The disadvantages are (1) that the cervix is still in place and in 1 to 2 per cent of cases subsequently is the site of carcinoma, and (2) that the cervical stump may become infected. Partial hysterectomy (Figs. 633 to 635) is a relatively simple

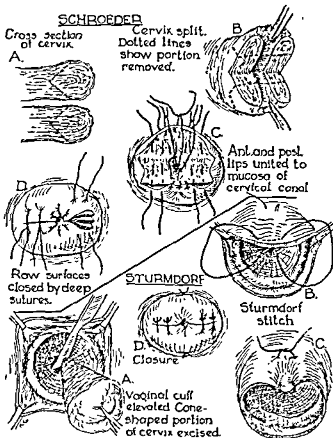


Fig. 632. TYPES OF CERVICAL REPAIR.
Curtis-Schroeder and Sturmdorf techniques, from Operative Procedure, published by Johnson and Johnson.

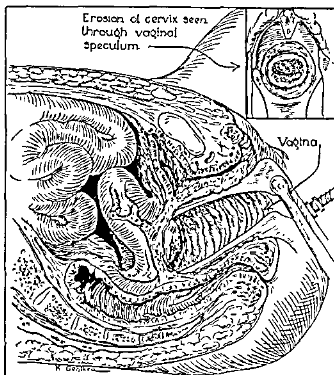


Fig. 630. SPECULUM EXAMINATION OF THE CERVIX.

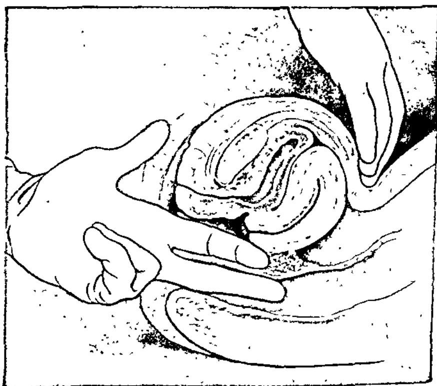


Fig. 631. BIMANUAL ABDOMINOVAGINORECTAL EXAMINATION.

This method of examination is a useful diagnostic procedure in the identification of deep-seated pelvic disease. (From Curtis: Textbook of Gynecology.)



Fig. 634. ABDOMINAL SUPRAVAGINAL OR PARTIAL HYSTERECTOMY (CONTINUED).

D, The uterus has been elevated and reflected forward and to the right; scissor dissection has stripped the posterior leaf of the right broad ligament from the uterine vessels as they pass downward along the uterus. The peritoneal incision is continued posteriorly over the uterine surface. A similar procedure has been begun on the left. *E*, The uterine vessels, which have been well isolated, are clamped bilaterally. *F*, The body of the uterus has been removed by a slightly concave incision. Amputation above the level of the internal os is preferable; incision through the cervix predisposes to infection. *G*, The uterine vessel clamps are replaced with "pulley" suture ligatures (From Curtis-Huffman: Textbook of Gynecology.)

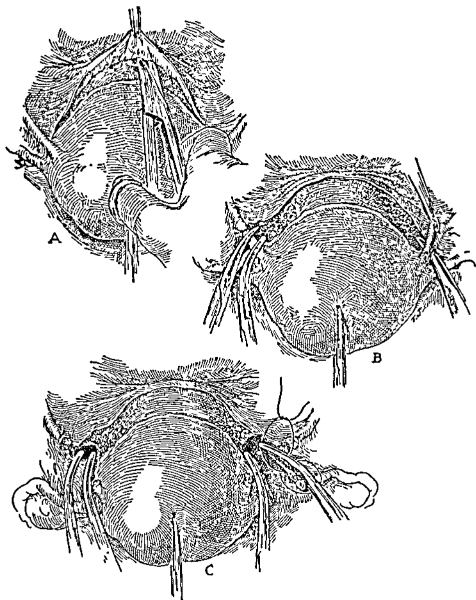


Fig. 633. ABDOMINAL SUPRAVAGINAL OR PARTIAL HYSTERECTOMY.

A, The uterus is pulled upward, exposing its anterior surface. The uterine reflection of the vesical peritoneum is divided and displaced downward a short distance by sharp dissection. *B*, The round ligaments are lifted with tissue forceps, undermined with curved forceps, ligated 1.5 cm. from the uterus, clamped proximally, and cut between the ligature and the clamp. *C*, The broad ligament is perforated by scissors in the thin spot slightly below where the round ligament has been cut. After clamps have been placed, the broad ligament is cut. A "pulley" suture ligature replaces the forceps. (From Curtis-Huffman: Textbook of Gynecology.)

operation and is similar in its early stages to total hysterectomy. The ovaries should be preserved whenever possible in women who have not passed the menopause.

Complete abdominal or *total hysterectomy* (*panhysterectomy*) is the removal of the entire uterus. The operation, as far as the ligation of the uterine vessels, is essentially the same as that outlined for partial hysterectomy. Downward dissection along the cervix is continued until the fornices along the vagina are opened laterally, posteriorly and anteriorly, and the entire uterus is removed (Figs. 636, 637).

In any type of hysterectomy, injuries to the bladder or ureters may occur, and the course of the latter must be well in mind (Figs. 617 to 619). Furthermore, normal anatomy or landmarks are often altered by earlier pelvic operations, previous infections, or infiltration by tumor tissue, so that wrongly placed sutures or hemostats may result in vesicovaginal or uterovaginal fistulae, cut ureters or ureteral strictures. In more difficult operations, outlining the ureters by preoperatively placed catheters is often done.

In a *radical panhysterectomy* (Fig. 638) the uterus must first be freed from its bed in order that the dissection of the glands in the base of

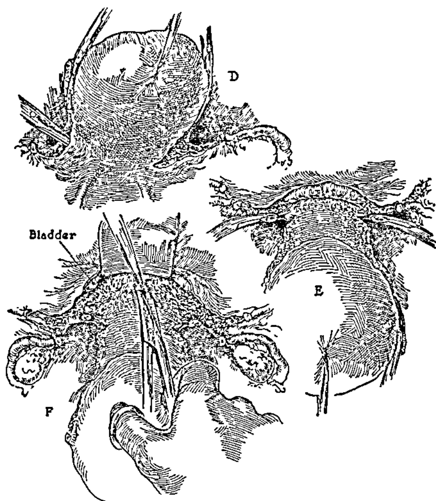


Fig. 636. COMPLETE ABDOMINAL OR TOTAL HYSTERECTOMY.

The first part of this operation is the same as for partial hysterectomy (Fig. 633). *D*, The uterus has been elevated and lifted forward and to the right. Scissor dissection strips the posterior leaf of the left broad ligament from the uterine vessels as they pass downward along the uterus; the peritoneal cut continues posteriorly, obliquely downward, over the uterine surface. This maneuver has been done on the right. *E*, The well isolated uterine vessels have been clamped bilaterally, cut above, and dissected slightly from their uterine attachments *F*, Relaxation induced by freeing the uterine vessels, together with freeing of the vesical fascia sheath surface to displace the bladder downward, well below the level of the cervix. (From Curtis-Huffman: Textbook of Gynecology.)

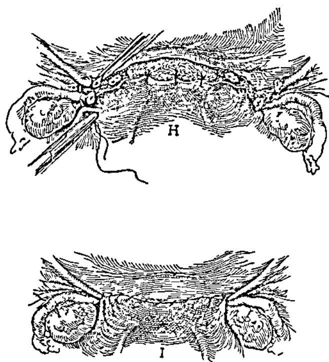


Fig. 635. ABDOMINAL SUPRAVAGINAL OR PARTIAL HYSTERECTOMY (CONCLUDED).

H, The cervical stump has been united by deep interrupted sutures. A suture has been placed on the left in such a manner as to cover the raw surfaces and at the same time to displace the ovary lateralward to lie freely in the ovarian fossa. *I*, The ligaments have been anchored without undue tension. They are usually routinely attached to the stump of the uterus, but this is not obligatory. The operation is completed by the reflection of the anterior peritoneal flap posterior to the line of closure of the uterus. *(From Curtis-Huffman: Textbook of Gynecology.)*

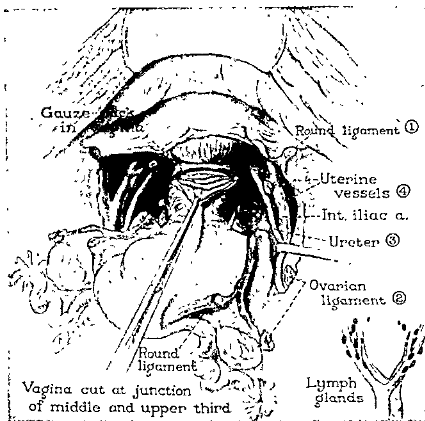


Fig. 638. RADICAL PANHYSTERECTOMY FOR CARCINOMA OF THE UTERUS.

An important part of the operation is a thorough dissection of the lymph nodes and fascia in the obturator space and along both internal and external iliac vessels. (From Masson: S. Clin. North America, 27: 763-74, 1947.)

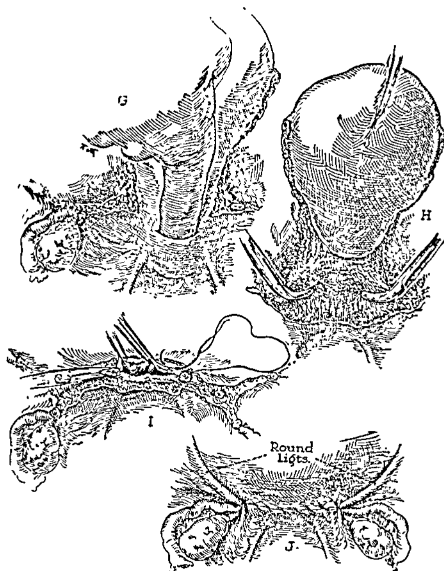


Fig. 637. COMPLETE ABDOMINAL OR TOTAL HYSTERECTOMY (CONTINUED).

G, A short transverse peritoneal incision has been made over the cervix posteriorly. Dissection downward with the scissors and continued with the finger separates the tissue within the cervicovaginal fascial sheath, to be followed by lateral enlargement of the incision solely through the peritoneum. *H*, With the peritoneum pushed downward and the uterus somewhat freed and elevated, hysterectomy clamps grasp the tissue obliquely, below the level of the cervix. *I*, The uterus has been removed. A figure-of-eight suture has ligated the vaginal branch of the right uterine artery, and a continuous suture approximates the vagina. J, Peritonealization is readily accomplished. (From Curtis-Huffman: Textbook of Gynecology.)

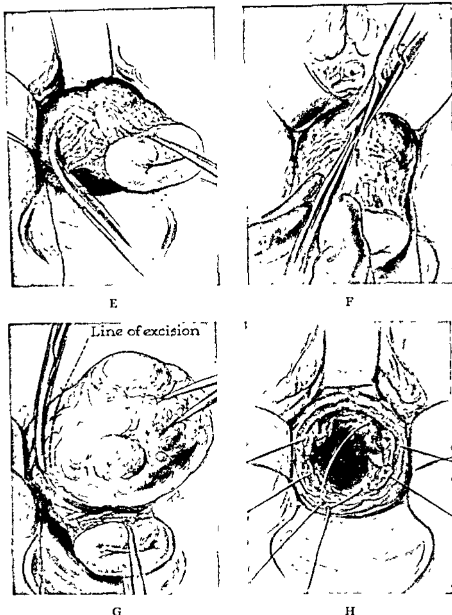


Fig. 640. VAGINAL HYSTERECTOMY (CONTINUED).

E, Opening the cul-de-sac and cutting and ligating the uterosacral ligaments have mobilized the uterus. The base of the broad ligament containing the uterine artery is clamped and will be divided, and the clamp replaced by a suture-ligature, the ends left long. *F*, The bladder has been further mobilized and displaced upward, exposing the vesical reflection of the peritoneum, which is incised. *G*, The fundus of the uterus has been delivered, and a clamp has been placed on the right broad ligament. The remaining portion of the ligament will be clamped from below and similarly divided. *H*, The uterus has been removed, and the clamps on the broad ligaments and uterosacral ligaments have been replaced by suture-ligatures, the ends left long. The peritoneum is closed on the right by successive bites, beginning at the vesical reflection of the peritoneum, including thereafter the stump of the broad ligament, the uterosacral ligaments and the peritoneum posteriorly. A similar suture on the left and an interrupted midline anteroposterior peritoneal suture complete the closure. (From Curtis-Huffman: Textbook of Gynecology.)

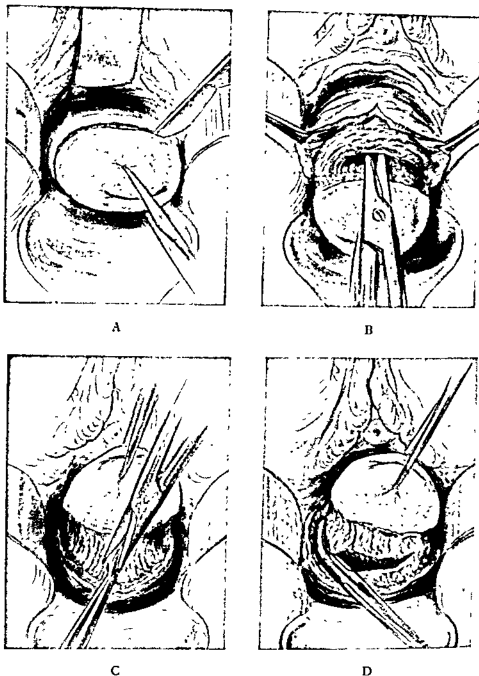


Fig. 639. VAGINAL HYSTERECTOMY.

A, With the uterus pulled down under tension, an incision with a knife encircles the cervix. *B*, The anterior vaginal wall has been slightly separated by blunt dissection and divided a short distance upward in the midline. The bladder is separated by blunt dissection and cutting of the pillars. *C*, A vaginal cuff has been separated from the cervix posteriorly. With the uterus pulled firmly forward, the peritoneum of the cul-de-sac is exposed to view and incised. *D*, Aided by the opening in the cul-de-sac, a hysterectomy clamp is placed on the uterosacral ligament. The clamped tissues will be divided and the clamp replaced by a suture-ligature, the ends left long. (From Curtis-Huffman: Textbook of Gynecology.)

the broad ligament can be performed without danger to the ureter. The vault of the vagina is then closed and peritonealized.

Vaginal hysterectomy, or removal of the uterus through the vaginal canal, may be performed when the vaginal outlet is relaxed sufficiently to afford an approach by the vaginal route. Dense adhesions or large tumors do not allow this approach. The operation permits rapid repair of the vaginal outlet, and a frequent indication for its use is uterine prolapse in elderly women (Figs. 639 to 641).

VESTIGIAL STRUCTURES. Pelvic disease may arise from vestigial elements of the embryonic wolffian (mesonephric) duct (Fig. 642). When the mesonephric duct persists, it is represented by a tube beginning close to the lateral extremity of the *tuba uterina* (Fallopii). This tube courses medially between the layers of the broad ligament and downward in the superficial tissue of the cervix and lateral aspect of the vagina to an opening at the vulva close to the orifice of Bartholin's gland. Usually no trace remains of Gartner's duct, which is the lower or uterovaginal segment of the wolffian duct. A vestige of the upper or mesosalpingial portion of the wolffian duct, the epoophoron, usually is found between the layers of the mesosalpinx or in the broad ligament. These fetal remnants may give rise to cystic tumors which are termed *parovarian cysts*. They vary in size, though usually they are not large, and generally are unilocular; sometimes they contain clear fluid. They may be mistaken for ovarian cysts; however, they always lie within the broad ligament. A parovarian cyst sometimes may be recognized by the greatly elongated uterine tube stretching over its upper surface. The cysts may burrow downward in the broad ligament and come into contact with, and adhere to, the ureter. In removal of these tumors the greatest danger is that of injuring the ureter. The tumors are approached best by downward dissection through the broad ligament.

SALPINGITIS. Salpingitis is infection of the uterine tube. The continuity of the mucosal lining of the uterus with that of the tube explains the readiness with which ascending infection, chiefly gonococcal, occurs. The scavenger action of peritoneal contact is responsible for tuberculous salpingitis, and lymphatic involvement for streptococcal salpingitis associated with pregnancy. The commonest result of tubal infection is the sealing up of the abdominal ostium by adhesions which tend to prevent the products of infection from entering the pelvic cavity. The secretions which collect in the infected tube, having insufficient drainage into the uterus, cause the tube to distend so that it may be palpated easily (*pus tube*, *pyosalpinx*). Absorption of the purulent exudate in the tube and its replacement by clear fluid results in *hydrosalpinx*, which resembles a retention cyst. The tube may be distended by blood (*hematosalpinx*).

Leakage of infective material into the pelvic cavity may produce a pelvic peritonitis which may extend upward and result in a *generalized peritonitis*, or remain localized and produce *adhesive pelvic peritonitis*. In the latter condition it is not uncommon to find the ovary, tube, the adjoining part of the broad ligament, one or more coils of small intestine and the sigmoid glued firmly together and adherent to the pelvic wall. This constitutes *adnexal disease*. When an infection occurs in both the tube and

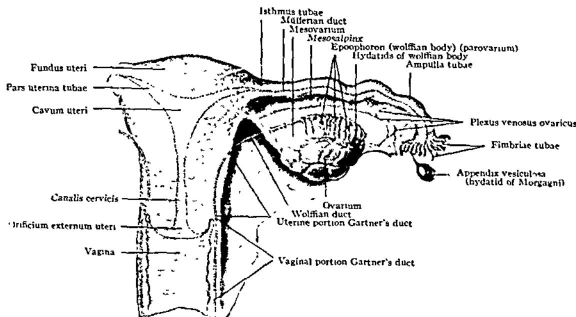


Fig. 642. RELATIONS OF THE MULLERIAN, WOLFFIAN AND GARTNER'S DUCTS TO THE UTERUS AND ADNEXA.

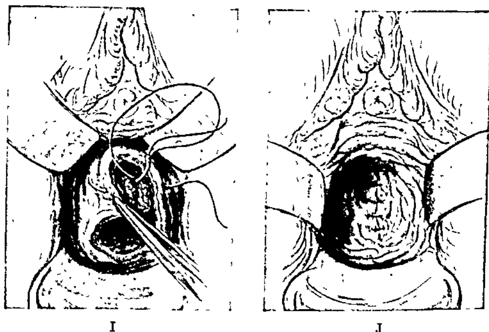


Fig. 641. VAGINAL HYSTERECTOMY (CONCLUDED).

I, The stumps of the broad ligaments will be slightly extraperitoneal. Some of their suture ends should be left long. Closure of the vaginal mucosa should be by interrupted sutures, usually placed transversely and anchored to the firm structures beneath. *J*, The vaginal vault should be firm, not rigid; every effort should be made to preserve the depth of the vagina.

If anterior delivery of the uterus is difficult, or if there is danger of injury to the bladder, the uterus may be delivered through the cul-de-sac, fundus first, the bladder separated last. Exceedingly difficult vaginal hysterectomy may be aided by complete amputation of the cervix, or the uterus may even be bisected throughout its length. A uterus containing massive tumors may be removed by morcellation, irrespective of its size, either with or without bisection. (From Curtis-Huffman: Textbook of Gynecology.)

adequate specialized mucosa like the endometrium in the uterus, the continued corrosive action of the trophoblastic cells causes a rupture of the tube. Rupture usually occurs between six and eight weeks after implantation, although it may take place earlier or later. Extrusion of the fetus into the lumen of the tube is *internal rupture*. A hematosalpinx results. If the fetus is extruded through the abdominal ostium (*tubal abortion*) (Fig. 643), the fetus dies or may become implanted on the peritoneum (*abdominal pregnancy*). This type of pregnancy may proceed to full term and a live child be obtained by abdominal section.

In the usual tubal pregnancy the corrosive action of the trophoblastic cells completely destroys the mucosa and the musculature, and *external rupture* occurs, usually accompanied by sharp pain and hemorrhage. Excessive loss of blood may produce shock. The free blood in the peritoneal cavity produces a general peritoneal irritation. Vaginal bleeding usually occurs with the breaking down of the decidua of the uterus. Repeated small hemorrhages may occur until the abnormal gestation is removed by excision of the tube.

Examination of the Tubes. In *bimanual pelvic examination* a tube of normal size and consistency cannot be palpated. An acutely inflamed tube becomes enlarged and indurated and usually prolapses into the rectouterine cul-de-sac, where it may be palpated and is painful. Movement of the cervix from side to side pulls upon the inflamed tubes and causes exquisite pain. In chronic tubal infection, adhesions about the tubes may be presupposed if the uterus and ovaries lack their normal mobility. In investigating the causes of sterility it is important to determine the patency of the tubes. Several methods are available for this determination. Gas under known manometric pressure may be passed into the cervical canal, uterine cavity and uterine tubes (*tubal insufflation*). Obstruction in the tubes prevents the passage of gas into the abdominal cavity.

The cavities of the uterus and tube may be visualized by the injection of a substance (*Lipiodol*) opaque to x-ray. The Lipiodol outlines the patent structures and normally escapes into the peritoneal cavity. Operative attempts to restore tubal patency require an exact knowledge of the location of the obstruction.

Salpingectomy and Salpingo-oophorectomy. *Salpingectomy*, or removal of the uterine tube (Fig. 644), may be unilateral or bilateral and may or may not be accompanied by removal of the corresponding ovary (salpingo-oophorectomy). The usual indications for the operation are residual infection and tubal pregnancy. There may be dense adhesions to the surrounding structures which require blunt or sharp dissection to mobilize the tube. The blood vessels to the tubes, branches of the ovarian vessels, then are clamped in the mesosalpinx and ligated separately to prevent kinking and occlusion of the main vessels. The blood supply to the ovary must be preserved

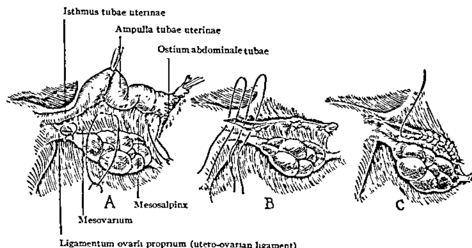


Fig. 644. Salpingectomy.

A, Elevation of the uterine tube, and placement of sutures. *B*, Removal of the tube, proximal to its uterine origin. *C*, Closure of the wound in the mesosalpinx.

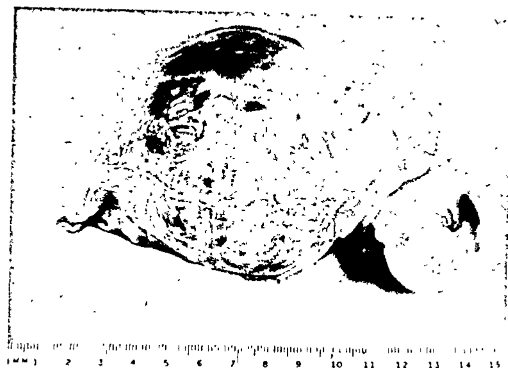


Fig. 643. TUBAL PREGNANCY: FETUS IN THIRD MONTH.
(Photograph provided by Dr. John Huffman.)

ovary, adhesions form between them and wall off a single pus cavity known as a *tubo-ovarian abscess*. There often is so much inflammation in the surrounding tissues that it is difficult to attribute to each structure its proper share in the symptom-complex. If the tubal exudate drains freely into the rectouterine cul-de-sac, a true *pelvic abscess* may develop. Pelvic abscesses may rupture spontaneously into the rectum, vagina, loops of intestine, or bladder. The rupture of a pus tube may cause extension of infection into the broad ligament and a *broad ligament abscess* may result. A pus tube rarely ruptures into the abdominal cavity.

Salpingitis, in the vast majority of instances, responds well to nonoperative treatment and, allowed to subside, often does not preclude subsequent pregnancy. Tuberculous salpingitis usually does not respond to nonoperative measures, but demands complete extirpation of all infected tissues.

ECTOPIC PREGNANCY. Various anatomic and pathologic conditions hinder the migration of the fertilized ovum to the normal area of implantation on the uterine mucosa: the arborescent system of folds in the tubal mucous membrane, in which the ovum may be sequestered, especially if the folds are swollen and adherent from a catarrhal inflammation (salpingitis follicularis); an abnormally long and excessively tortuous tube; congenital atresia or pathologic atresia after fertilization has taken place; adhesions which may have exerted a distorting influence on the tube; and destruction of the columnar epithelium of the mucosa.

A *tubal pregnancy* is by far the commonest form of ectopic gestation. Pregnancy in both tubes may occur simultaneously or separately. The implantation generally is in the lateral portion of the ampulla, but it may take place at any point, from the fimbriated extremity to the uterine ostium. *Primary abdominal pregnancies* occur rarely, and the fertilized ovum is unlikely to be implanted on the ovary (*ovarian pregnancy*). The principal cause of the interruption of the pregnancy is hemorrhage which separates the placenta and deprives the embryo of nourishment. When *pregnancy occurs in the fimbriated extremity of the tube*, the fetus develops partly in the cavity of the infundibulum and partly in the pelvic cavity in that vicinity. The ovum may be arrested near the uterine ostium of the tube, and the fetus may develop within the wall of the uterus (*interstitial pregnancy*).

When the fertilized ovum becomes embedded in the wall of the uterine tube (*tubal pregnancy*), the trophoblastic cells invade the mucosa and musculature of the tube. Because the musculature is thin and there is not an

adhesions and sclerosed areas in the ovary. Subsequent swelling of the "buried" ovary, as a result of the development of graafian follicles, distends the adhesions and peritoneum and causes "ovarian pain." *Streptococcal infection* usually is puerperal or follows surgery on the genital tract; it is particularly frequent after an infected abortion. The condition is nonoperable, since intervention tends to disseminate infection and cause a generalized peritonitis or a bacteremia.

Tuberculous infection in the ovary is not infrequent and is always secondary to tubal involvement. The condition requires removal of the tube and ovary.

OVARIAN CYSTS. Cyst formation may result from failure of completion of the normal physiologic processes in the ovary. The multiple development of graafian follicles which fail to mature may produce multiple small cysts (*retention cysts*) from 1 to 2 cm. in diameter. These cysts usually are thin-walled and are filled with clear fluid. They occur more often in chronically inflamed and sclerosed ovaries.

Failure of a large corpus luteum hematoma to absorb may result in a *corpus luteum cyst.* These cysts usually are larger than retention cysts and may measure from 8 to 10 cm. in diameter. The thin cyst wall may have a characteristic color from retained carotin, and the cyst contents usually are colored by blood pigments, generally hemosiderin. When these cysts are large and filled with blood, they are known as *corpus luteum hematomas.*

Endometrial cysts of the ovary, *endometriomas* (chocolate or Samson cysts), often are mistaken for corpus luteum hematomas. The endometrial cysts arise from aberrant endometrium which undergoes changes similar to those in the uterus during menstruation. Since there is no egress of blood unless rupture of the cyst occurs, the menstruum progressively distends the cyst.

ANOMALIES OF THE VAGINA. When the vagina is absent, the uterus and uterine tubes are rudimentary or absent. A congenital septum, usually of mucous membrane, sometimes occurs in the upper part of the vagina. The cervix may be hidden entirely by the septum, and the communication from the vulva to the vaginal vault be but a small orifice on one side. A septum occasionally extends transversely across the entire vagina (*atresia*). If the partition or septum between the müllerian ducts is not absorbed in the fusion, the result is a *septate uterus* and a *double vagina.* The septum of

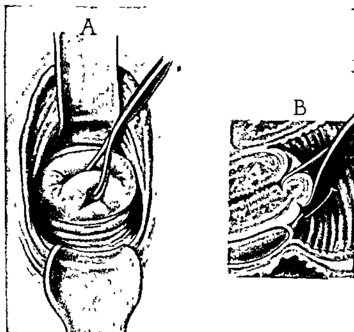


Fig. 645. POSTERIOR COLPOTOMY FOR RECTOUTERINE CUL-DE-SAC ABSCESS.

A, The cervix is drawn upward and forward; the horizontal black line marks the incision through the vaginal mucosa. *B*, Sagittal section showing the location of the abscess; the arrow indicates the incision for drainage.

to prevent degeneration of the ovary and the formation of ovarian cysts. The uterine portion of the tube with a wedge-shaped portion of the cornu of the uterus is excised, and the tube is freed from the mesosalpinx. The uterine wedge is closed carefully by suture, and the edges of the mesosalpinx are sutured to the peritoneum of the broad ligament below the round ligament to peritonealize the raw surfaces and aid in the suspension of the ovary.

Removal of the tube with the corresponding ovary (*salpingo-oophorectomy*) is simpler than removal of the tube alone. After exposing the tube and ovary and freeing them from adhesions, ligation of the ovarian vessels in the suspensory ligament of the ovary may be performed. The uterine portion of the tube is removed as in salpingectomy, and the uterine vessels are ligated at or just below the cornu. The tube and ovary then are removed, with little or no bleeding.

ABNORMAL POSITIONS OF THE OVARY. The ovary, like the testis, originates in the lumbar region. At birth the ovary is found at the medial border of the psoas muscle; subsequently it migrates to its permanent site. In multiparae the ovary lies fairly constantly in the "ovarian fossa." Because of its freedom within the peritoneal duplication of the mesovarium, the ovary is mobile.

The principal conditions causing the ovary to assume an ectopic position are retroversion and retroflexion of the uterus; failure of the overstretched peritoneum of the broad ligament to return to the normal state after parturition; and ovarian enlargement. Displacement may be temporary, but frequently is permanent because of the development of adhesions. The ovary, in an abnormal position, often becomes tender and painful.

The ovary may lie behind the ureter and hypogastric vessels in close relation to the uterosacral fold, or may gravitate into the rectouterine cul-de-sac (Fig. 617). It may occupy an entirely ectopic position in the sac of an inguinal or femoral hernia. It has a gubernaculum which sometimes anchors it in the inguinal canal with the round ligament. The descent of the ovary, like that of the testis (Fig. 366, p. 376), is accompanied by a tubular process of peritoneum (canal of Nuck), which normally disappears. Persistence of this process affords a sac for a congenital inguinal hernia. Cysts in the inguinal canal and in the labium majus develop from remnants of the primitive peritoneal canal, and their development is analogous to that of vaginal hydrocele and cyst of the spermatic cord (p. 377).

HEMORRHAGE FROM THE OVARY. The ova are formed and matured in the substance of the cortical ovarian stroma, each in a small cyst (*graafian follicle*). The follicle, by enlargement, reaches the surface of the ovary. The mature follicle bursts as a result of the increasing tension of the fluid filling it. This fluid and the ovum floating within it are discharged into the peritoneal cavity, whence the ovum is directed into the uterine tube by the fimbriae and propagated into the uterine cavity by the cilia and tubal peristalsis. The cavity of the ruptured follicle fills with blood and constitutes a *corpus luteum*. Occasionally hemorrhage is excessive and produces a corpus luteum hematoma which may be palpable on bimanual examination. If the bleeding continues, the hematoma may rupture and discharge its contents into the peritoneal cavity.

INFLAMMATION OF THE OVARY. The ovary contains an unusual variety of energetic cellular elements which vary in morphology and functional activity in successive periods of life. The ovary is subject to pathologic processes, and, although involved most frequently during the reproductive period, is by no means exempt from involvement either in infancy or in old age.

"Oophoritis" is the result of a direct invasion of the ovary by microorganisms. An acute involvement is characterized by swelling, congestion and leukocytic infiltration causing formation of a serous, bloody or purulent exudate. The most common causative organisms are the gonococcus and the streptococcus. The dense cortical stroma of the ovary is resistant to infection, but the ruptured graafian follicle or a corpus luteum hematoma is a portal of entry for, and a site for development of, infection. Oophoritis occurs only during a severe pelvic infection.

Gonococcal oophoritis is the result of an infection ascending through the uterus and tubes, and finally reaching the ovary. It is secondary to, and part of, a pelvic peritonitis caused by dissemination of the infection through the fimbriated end of the tube. When infection enters a corpus luteum, a *corpus luteum abscess* is formed. The characteristic results are the formation of dense periovarian

adhesions and sclerosed areas in the ovary. Subsequent swelling of the "buried" ovary, as a result of the development of graafian follicles, distends the adhesions and peritoneum and causes "ovarian pain." *Streptococcal infection* usually is puerperal or follows surgery on the genital tract; it is particularly frequent after an infected abortion. The condition is nonoperable, since intervention tends to disseminate infection and cause a generalized peritonitis or a bacteremia.

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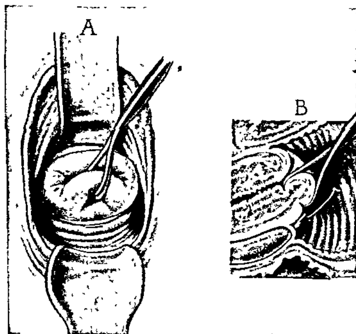


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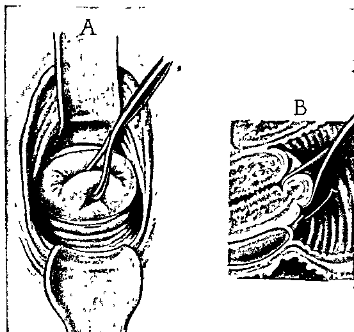


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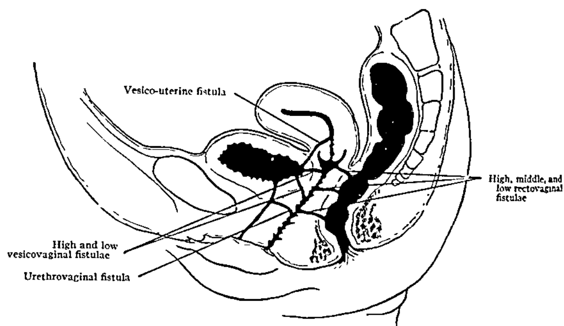


Fig. 646. VAGINAL FISTULAE.

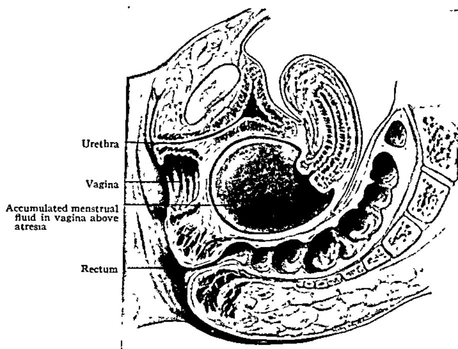


Fig. 647. HEMATOCOLPOS FROM VAGINAL ATRESIA.

the double vagina usually is falciform in shape, and may extend the whole length of the vagina or be found only in the upper, middle or lower third. There may be an atresia of one or the other half of the double vagina. The menstrual flow may be retained within a rudimentary vagina lying beside a well developed vagina. If tension becomes sufficiently great in the vaginal pocket, a small opening may form and allow the fluid to escape into the functioning vagina.

The posterior vaginal wall in the posterior fornix is related to the peritoneum of the rectouterine cul-de-sac (of Douglas). The segment of the vagina related to the rectouterine cul-de-sac is made accessible by drawing the cervix anteriorly (Fig. 645). This maneuver affords exposure for incision into the pelvic cavity for evacuation of a cul-de-sac abscess (*posterior colpotomy*). Inferiorly, the posterior vaginal wall is related to the anterior surface of the ampulla of the rectum; only a thin layer of connective tissue intervenes.

Vesicovaginal Fistulae. In difficult and prolonged labor there is constant pressure of the anterior vaginal wall against the pubic arch. This pressure may cause a sloughing of the vaginal wall and the contiguous portion of the bladder with subsequent establishment of a vesicovaginal fistula (Fig. 646). The condition causes much distress because of the continuous flow of urine from the vagina. Fistulous communications are distinguished according to their locations. *High fistulae* occur in the fundus or base of the bladder, are difficult of surgical approach by the vagina, and may require suture through the bladder cavity. *Middle fistulae* involve the trigone, and *low fistulae* involve the urethra. The vaginal fistula may involve the ureter (*ureterovaginal fistula*). *Urethrovaginal fistulae* are distinguished from vesicovaginal fistulae by the fact that they allow urine to escape from the vagina only during micturition.

Rectovaginal Fistulae. Rectovaginal fistulae are abnormal channels of communication between the rectum and vagina (Fig. 646). The common cause of fistulae in the upper part of the vagina is an extension of a carcinoma of the cervix to the vagina and into the rectum through the rectovaginal septum. The fistulae may follow destruction of the septum in severe labor.

During parturition the posterior commissure of the vagina may be torn, and the laceration may involve the skin and superficial tissue as far as the anus. The posterior wall of the vagina, the perineal body and the anal sphincters also may be involved.

Cystocele. Cystocele is a hernia of the bladder through the vesicovaginal septum. Some degree of prolapse of the urethra, *urethrocele*, with relaxation of the vesical sphincter, usually accompanies it. Cystocele results from stretching and tearing of the pubocervical connective tissue. The weakest spot usually is at the vesicocervical junction. A patient with cystocele complains of a protruding mass. Urinary incontinence frequently is present. Sometimes an examination in the standing position is necessary to demonstrate the lesion. The steps in the surgical repair of the lesion are indicated in Figures 648 to 652.

Perineal Laceration and Rectocele. The important perineal muscles related to the vaginal cleft in the urogenital diaphragm are the paired pubococcygeal bands of the anal levators (Figs. 696, 697; *cf.* Figs. 567, 568). From pubic origin, lateral to the symphysis, these fascia-covered muscles converge on the rectum to insert on the coccyx. Forward of the rectum, their margins hem the interlevator cleft, through which the vagina, almost exclusively a pelvic structure, emerges. Injury to, and subsequent retraction of, these muscles and their clothing and intervening fascia are the result of stretching and tearing.

As a result of this damage to these supporting structures, the rectum may protrude anteriorly through the posterior vaginal wall (*rectocele*). This is a true hernia, comparable with cystocele in the anterior vaginal wall. The protruding rectal sac may be near the vulvar orifice, or it may be high on the posterior vaginal wall. Essentially, repair of a rectocele approximates the retracted medial margins of the levators after a flap of posterior vaginal mucosa and connective tissue has been dissected forward to allow operative manipulation.

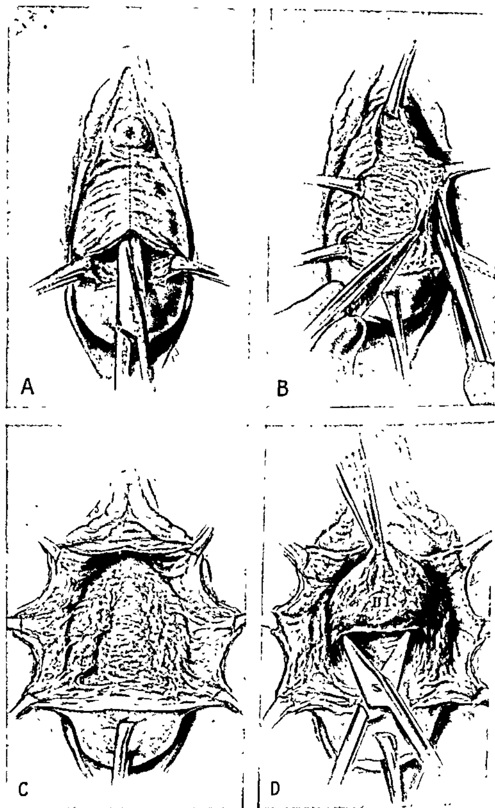


Fig. 648. ADVANCEMENT OPERATION FOR CYSTOCELE.

A, After a short transverse incision the musculofascial plane which separates the vagina from the bladder is easily found, and a pathway is made by blunt dissection with curved Mayo scissors. *B*, Each vaginal flap has considerable thickness and is composed of mucosa with firmly adherent, dense, underlying musculofascial tissue. By blunt dissection with curved scissors this tissue is readily separated from the mucosa lateralward for a distance of several centimeters. *C*, In patients with marked incontinence dissection of the musculofascial tissue should be made with unusual thoroughness in the region of the urethra. This tissue is chiefly the urogenital diaphragm. *D*, The bladder is separated from the cervix.

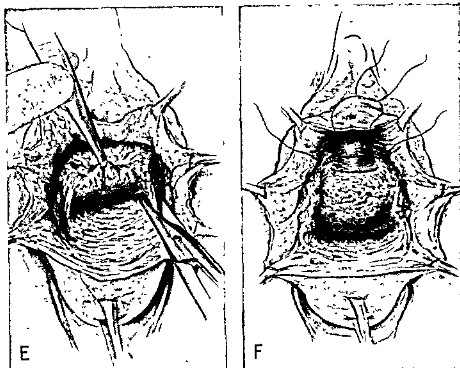


Fig. 649. ADVANCEMENT OPERATION FOR CYSTOCELE (CONTINUED).

E, The pillars are cut, and the bladder is pushed upward. *F*, If there has been incontinence, the procedure for incontinence of urine is now carried out. If incontinence is a lesser factor, sutures of fine silk or fine catgut are placed as indicated. (From Curtis-Huffman: Textbook of Gynecology.)

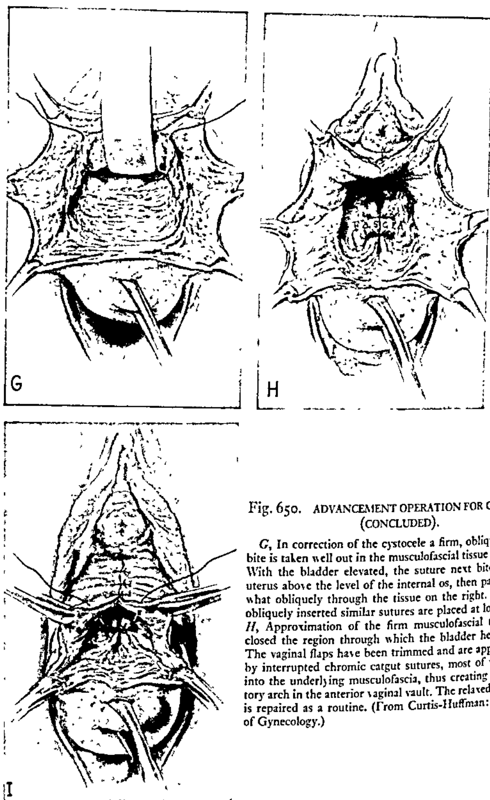


Fig. 650. ADVANCEMENT OPERATION FOR CYSTOCEL (CONCLUDED).

G, In correction of the cystocele a firm, obliquely plac bite is taken well out in the musculofascial tissue on the lef With the bladder elevated, the suture next bites into th uterus above the level of the internal os, then passes some what obliquely through the tissue on the right. Addition obliquely inserted similar sutures are placed at lower level *H*, Approximation of the firm musculofascial tissues ha closed the region through which the bladder herniated. *I* The vaginal flaps have been trimmed and are approximate by interrupted chromic catgut sutures, most of which bit into the underlying musculofascia, thus creating a satisfac tory arch in the anterior vaginal vault. The relaxed perineum is repaired as a routine. (From Curtis-Huffman: Textbook of Gynecology.)

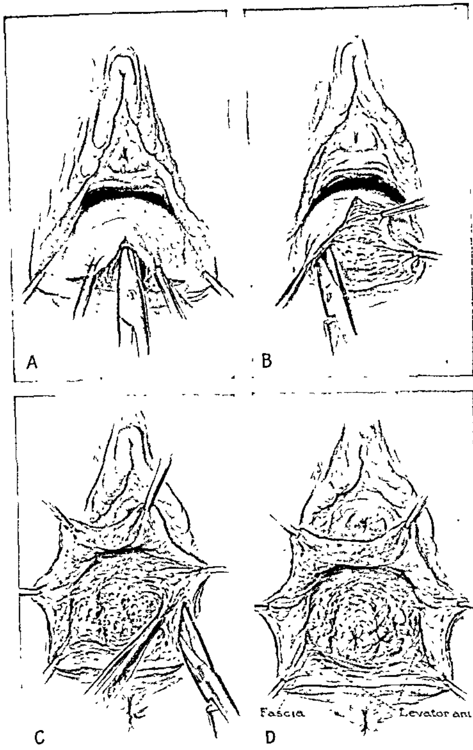


Fig. 651. REPAIR OF LACERATION WITH RECTOCELE.

A, Relatively short transverse strip of mucosa has been removed at the vulvovaginal juncture. This incision may be lengthened later, but has now been made as short as possible in order to minimize the danger of vaginal constriction in closure, a frequent complication of rectocele repair. Blunt dissection with the scissors is creating a pathway in the fascial plane which separates the vagina from the rectum *B*, A wedge of vaginal mucosa has been removed from the midline. By blunt dissection with Mayo scissors, the firmly adherent underlying musculofascia is readily separated from the vaginal mucosa. *C*, The vaginal mucosa is freed from the musculofascia, lateralward, on either side, well beyond the rectocele. *D*, The bulging rectocele which appears in the midline has been thoroughly freed and separated just as one dissects any other hernial sac. "Fascia" includes the musculofascial sheaths of the vagina and rectum. "Levator ani" of clinical parlance includes, not only the levators, but also the urogenital diaphragm and some sphincter ani fibers.

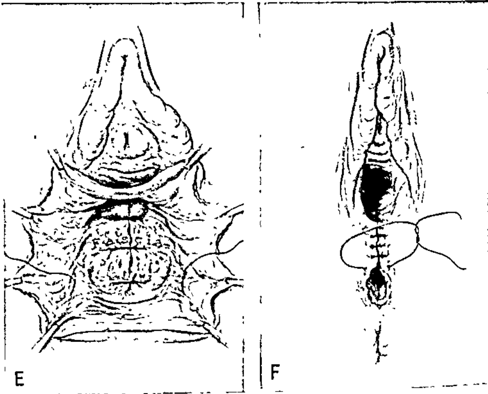
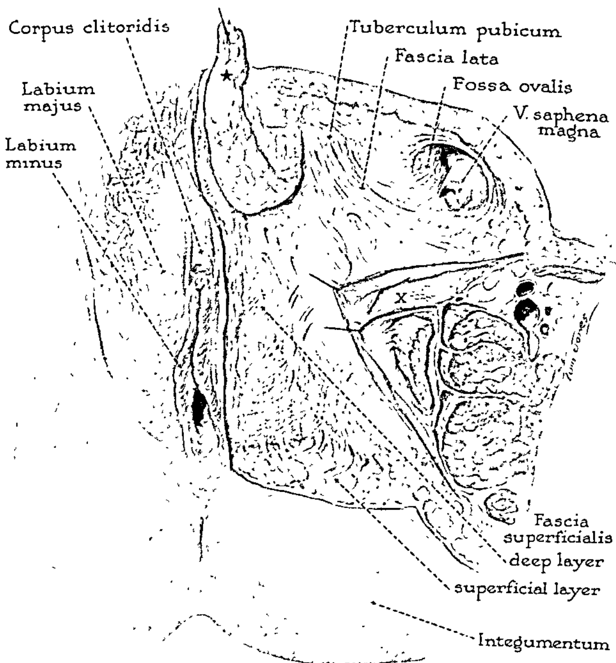


Fig. 652. REPAIR OF LACERATION WITH RECTOCELE (CONTINUED).

E, Bites placed firmly and obliquely in heavy musculofascia have united it over the rectocele. The surgeon routinely makes use of a finger in the rectum while placing these sutures. One obliquely inserted suture has been placed in both "levators"; one or two more will be similarly placed. *F*, The vaginal flaps, trimmed as required, are approximated by finest chromic catgut sutures, with occasional tacking to the underlying tissues to prevent the formation of a dead space. (From Curtis-Huffman' Textbook of Gynecology.)

PART VI

The Perineum



FEMALE PERINEUM; SUBCUTANEOUS LAYERS

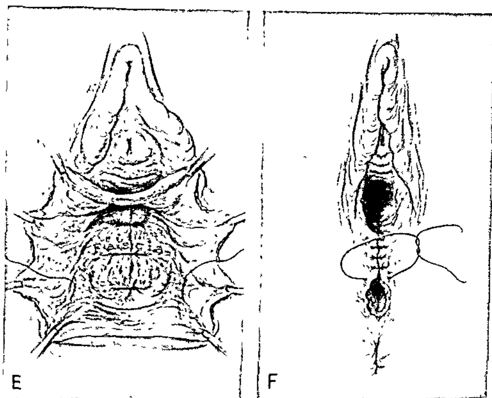


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CHAPTER 21

Male Perineum

The perineum is a partition of soft parts extending from one lateral pelvic wall to the other between the pubis and coccyx (Fig. 653; *cf.* Fig. 693). It includes the musculomembranous pelvic diaphragm and those soft parts at the pelvic outlet lying inferior to it. At the pelvic outlet all the boundaries—the pubic symphysis, ischiopubic rami, ischial tuberosities, sacrotuberous ligaments, and coccyx—can be palpated.

The region is subdivided into two triangular portions by a transverse line just anterior to the ischial tuberosities, the midpoint of which lies just anterior to the anal orifice. The area in front of this line is known as the anterior or urogenital triangle, and that behind it as the posterior or anal triangle. Although the relations of the anal canal to the anal triangle differ but little between the sexes, the urogenital relations differ widely.

The male perineum, exclusive of the external genitals, has unusual interest for the surgeon because of the relationship it bears to the deeper stages of the urethra, prostate, seminal vesicles, bladder and rectum. It is divided into the pelvic diaphragm, the anterior or urogenital perineum, and the posterior or anal perineum.

Diaphragmatic Supports

The pelvic diaphragm is a musculomembranous partition which forms the lower boundary and floor of the pelvic basin and is the framework for the perineum. Viewed from above, the diaphragm presents the appearance of a hollow cone, at the most dependent part (apex) of which the rectum emerges on the perineum (Figs. 567, 568). It is divided into the main pelvic diaphragm, consisting of the levator ani muscles, and the accessory or urogenital diaphragm, composed chiefly of aponeurotic elements (Fig. 659).

The muscles forming the diaphragm, the levator ani and coccygeus, spread like a sling from the walls of the pelvis to the anus. They have a continuous line of attachment to the inner aspect of the pelvic wall from a point

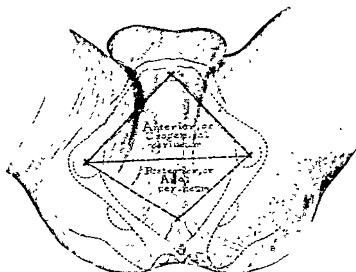


Fig. 653. TOPOGRAPHY OF THE MALE PERINEUM.

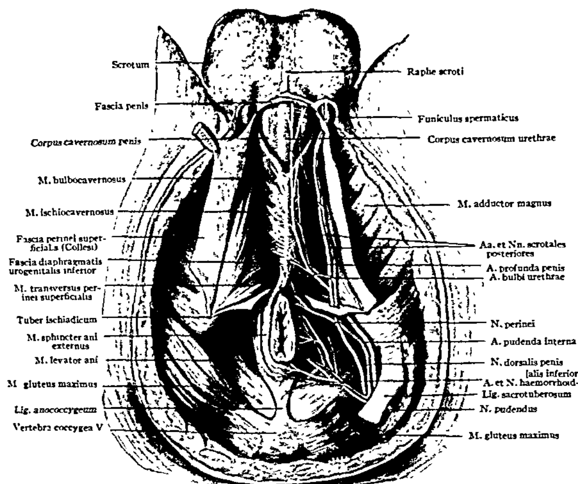


Fig. 654. SUPERFICIAL STRUCTURES OF THE MALE PERINEUM.

The superficial perineal fascia (of Colles) has been incised and retracted to show the contents of the superficial perineal compartment.

by a definite membranous partition, the urogenital diaphragm (triangular ligament), which extends across the pubic arch in somewhat the same way that the mylohyoid muscles extend between the mandibles to separate the floor of the mouth from the sublingual space (Fig. 141, p. 149). The divisions formed are the superficial and deep compartments of the urogenital perineum.

SUPERFICIAL STRUCTURES. Save for minor branches of the inferior hemorrhoidal, pudendal and posterior scrotal vessels and nerves, little of interest attaches to the superficial structures of the anterior perineum except the *derivation of the* SUPERFICIAL FASCIA (Figs. 654 to 656). This fascia consists of two strata, the *outer* of which is a fatty layer continuous with the general fatty covering of the body, particularly that investing the scrotum, thighs, penis and anterior abdominal wall (Fig. 685). It contains little fatty tissue except at its peripheral part, but consists of smooth muscle fibers which are continuous anteriorly with the dartos layer of the scrotum. The *inner* or *deeper layer*, *Colles' fascia*, is found only over the urogenital region. It is denser and more membranous than the superficial layer, and is attached on each side to the periosteum of the pubic arch. Behind, it is fused with the base of the triangular ligament. It passes anteriorly over the scrotum and penis and along the spermatic cord to the anterior abdominal wall, where it is continuous with the corresponding deeper layer of the superficial fascia (Fig. 694). This continuous *layer encloses the penis, envelops the scrotum,* and forms a roof for the superficial perineal pouch. In extensive urinary extravasation or hemorrhage into the space, the actual lines of attachment of the fascia are demonstrated.

SUPERFICIAL PERINEAL COMPARTMENT. The

near the lower border of the symphysis anteriorly to the ischial spine posteriorly. From this extensive origin on each side the muscle fibers blend into a thick sheet and are directed with varying degrees of obliquity toward the median raphe. The more anterior fibers from the pubic bones support the base of the bladder and the prostate as these muscles converge to the central point of the perineum (Fig. 694). Their mesial margins are hemmed by aponeuroses which adhere to the lateral margins of the prostate and are known as the *lateral puboprostatic ligaments*. Because the pubic origin of the levators is considerably lateral to the symphysis, the muscular diaphragm is incomplete anteriorly, leaving a small anterior hiatus (*interlevator cleft*), against the inferior aspect of which lies the urogenital or accessory pelvic diaphragm.

An extension from the *pelvic fascia* invests the upper surface of the diaphragm and furnishes ensheathing prolongations to the structures lying upon the pelvic floor. The lower or perineal aspect of the levator ani muscle is closed by a thin membrane of the inferior levator fascia, while the adjoining aspect of the pelvic wall is clothed by the obturator or parietal layer of the pelvic fascia (Fig. 659).

The urogenital diaphragm (triangular ligament) is that part of the pelvic floor occupying the pubic angle and separating the soft parts of the perineum from the contents of the pelvis anteriorly. The essentially aponeurotic bundle of fibers, of which it is composed, stretches transversely from one ischiopubic ramus to the other, terminating posteriorly at the level of the ischial tuberosities by a posterior free border. The point in the pelvic floor between the levator margins and the posterior edge of the urogenital diaphragm would be weak were it not for the dense union between these structures anterior to the anus at the tendinous point of the perineum (*cf.* Fig 694, female perineum). The urogenital diaphragm is composed of superior and inferior layers of fascia separated by various structures (*cf.* Fig. 696). The superior layer of the diaphragm is densely adherent to the mesial edges of the levators, and, to a great extent, maintains the base of the bladder and the prostate within the pelvic cavity.

Interlevator Cleft. The hiatus between the mesial margins of the levators anterior to the rectum is known as the interlevator cleft or anterior prostatic space (Fig. 568). The floor is the superior fascia of the urogenital diaphragm; the roof, the base of the bladder. The space contains a quantity of loose areolar tissue, within which run the *middle pubovesical* and *puboprostatic ligaments*, all derived from the superior division of the pelvic fascia. These ligaments attach anteriorly to the pubes on each side of the symphysis, and run backward to insert into the capsule of the prostate and the antero-inferior surface of the bladder.

About the ligaments lie the *anterior prostatic venous plexuses*, definitely superficial to the capsule of the prostate. They are derived from the dorsal vein of the penis, after that vessel has passed anterior to the superior fascia of the urogenital diaphragm, and they terminate in the internal iliac veins. The plexuses are continued backward on each side about the lateral aspects of the prostate and there join the large, thin-walled veins lying in the sulcus between the bladder wall and prostate (p. 617). If hemorrhage is to be avoided, only blunt dissection should be used in exposure of the lateral surface of the prostate in radical removal of the gland for carcinoma or in manipulation to free the seminal vesicles.

Anterior or Urogenital Division of the Perineum

The anterior and posterior regions of the perineum should not be regarded as isolated in either the male or female. Both regions are related intimately to their common levator substratum, have a common blood supply and innervation by the internal pudendal vessels and nerves, and jointly participate in the formation of the central region of the perineum.

The framework of the anterior perineum is adapted especially to support the anterior pelvic structures and is specialized for, and differentiated by, the passage of the urogenital apparatus, the injuries and diseases of which give the area clinical and operative significance.

Definition and Boundaries. The urogenital perineum extends from the pubic symphysis to the central area of the perineum just anterior to the anus, and is limited laterally by the pubic arch (Figs. 654 to 658). Its contents consist of all the structures located between the anterior portion of the levator diaphragm above and the skin overlying the triangle below (Fig. 659).

The space is divided into two compartments

superficial compartment of the urogenital perineum is a space bounded inferiorly by Colles' fascia, and superiorly by the urogenital diaphragm (Figs. 659, 700). It is closed posteriorly and laterally by the fusion of its two walls and their attachment to the pubic arch. Anteriorly, the space communicates freely with the cellular interval between Scarpa's layer of the superficial fascia of the abdominal wall and the anterior rectus sheath (Fig. 676). The compartment is divided incompletely into two spaces by a median septum extending from the deep aspect of Colles' fascia to the superficial aspect of the bulbocavernosus muscle. It is evident that the natural outlet of the compartment is anterior, and that it is closed securely both posteriorly and laterally.

Within the superficial perineal pouch are the roots or fixed portions of the corpora cavernosa of the penis and urethra, their overlying ischiocavernosus and bulbocavernosus muscles, and those branches of the internal pudendal vessels and nerves which pierce the inferior fascia of the urogenital diaphragm to reach the space (Figs. 654 to 656).

The two roots of the *corpora cavernosa of the penis* arise from the midportion of the ischiopubic rami and run obliquely upward and forward, adhering to the periosteum of the descending rami of the pubes and to the inferior surface of the urogenital diaphragm. Each cavernous body of the penis is covered by the ischiocavernosus muscle. The *corpus cavernosum (spongiosum) urethrae* encloses the urethral canal and is directed forward to form the central body of the penis. Before the cavernous part of the *urethra* engages into its covering, it presents a dilation on its inferior surface, known as the cul-de-sac of the bulb. In passing a urethral sound, the tip of the instrument usually engages in this depression and may be forced into a false passage. This mishap is avoided by following the upper rather than the lower wall of the canal into the membranous and prostatic portions of the urethra. Gonorrheal urethritis often is chronic in the cul-de-

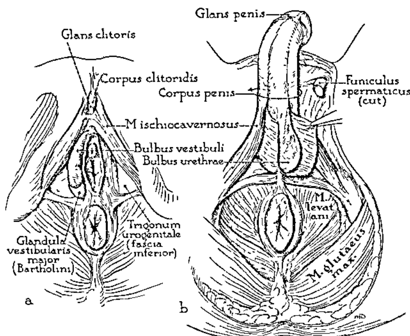


Fig. 657. ANATOMY OF THE FEMALE AND MALE PERINEUMS, ESPECIALLY OF THE SUPERFICIAL PERINEAL COMPARTMENT.

In the male specimen (*b*) superficial perineal muscles, penile constituents and the following boundaries of the anal portion are shown: levator ani muscle (of pelvic diaphragm) and external and sphincter muscle. In the female specimen (*a*) the external anal sphincter is shown in its relation to the superficial transverse perineal and bulbocavernosus muscles. In the male the bulbocavernosus muscle has been reflected on one side in order to expose a lateral half of the bulb of the urethra; in the female the homologous muscle has been removed (on the left) to reveal a bulb of the vestibule and the bulbourethral gland. In both specimens the crura are covered by the ischiocavernosus muscles. The bulbs of the vestibule, the intermediate mass and the glands of the clitoris are, together, homologous to the corpus cavernosus urethrae of the male.

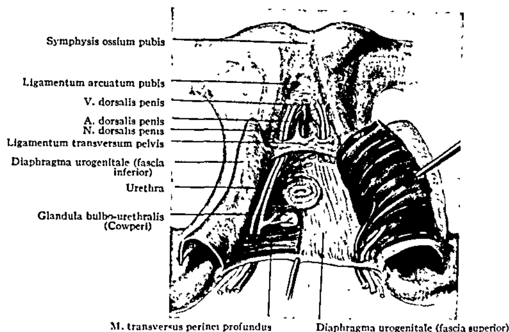


Fig. 655. CONTENTS OF THE DEEP PERINEAL COMPARTMENT LYING BETWEEN THE FASCIAE OF THE URO-GENITAL DIAPHRAGM.

Scrotum
Testis
Corpus cavernosum urethrae
Funiculus spermaticus
Fascia perinei superficialis (Collesi)
A. et N. dorsalis penis
Corpus cavernosum penis
Fascia diaphragmatis urogenitalis { inferior / superior
M. sphincter urethrae membranaceae
A. bulbi urethrae
A. pudenda interna
N. perinei
N. pudendus
M. transversus perinei profundus
Glandula bulbo-urethralis (Cowperi)
Urethra
Bulbus urethrae
Lig. arcuatum pubis
Aa. et Nn. scrotales posteriores
V. dorsalis penis
Lig. transversum pelvis
M. adductor magnus
M. ischiocavernosus
Bulbus urethrae
M. transversus perinei superficialis
Vv. pudendae internae
A. et N. haemorrhoidalis inferior

Fig. 656. DEEP STRUCTURES OF THE PERINEUM.

On the left the superficial perineal fascia (of Colles) has been incised and retracted to show the contents of the superficial perineal compartment. On the right the structures of the deep perineal compartment are exposed through an incision in the inferior fascia of the diaphragm. The inset shows the relation of the bulbourethral gland and duct to the urethra.

structure attached to the ischiopubic rami and stretched tightly across the pubic arch to assist in closing the forward part of the pelvic outlet. It separates the perineum from the pelvis anteriorly (Figs. 655, 658). The closed interval, or pouch, separating the layers of the diaphragm is filled principally with the muscle tissue about the membranous urethra. The two fascial layers blend with one another, with Colles' fascia and with the central point of the perineum posteriorly, and are attached to the margins of the pubic arch. The *inferior fascia* (*superficial layer of the triangular ligament*) alone has any strength, though it is deficient immediately behind the subpubic angle and ligament. Its anterior free margin is somewhat thickened and is known as the transverse perineal ligament. This fascia forms the deep wall of the superficial perineal compartment. The dorsal vessels and nerves of the penis pierce the inferior fascia of the urogenital diaphragm. The *superior layer* of the urogenital diaphragm is an undifferentiated fibrous structure continuous with the parietal pelvic fascia through the small interlevator cleft.

Deep Perineal Compartment. The space between the two layers of the urogenital diaphragm is known as the deep perineal compartment (Figs. 655, 658). It is related on its deep aspect with the pubic recess or anterior prolongation of the ischiorectal fossa, the slitlike space on each side between the levator ani and obturator internus muscles. It contains the deep transverse perineal muscle, the membranous urethra and its sphincter, the bulbourethral glands (of Cowper), the artery to the bulb, the internal pudendal vessels and the dorsal nerve to the penis.

The *deep transverse perineal muscle* is so interrelated and fused with superior fascia of the diaphragm as to render it difficult of dissection. Recognition of the muscle is made more difficult because of the tendency of the surrounding tissues to become so infiltrated as to present the appearance of muscle fibers. Each muscle runs from the ramus of the ischium to the midline, where it interlaces in a tendinous raphe with its opposite fellow (Fig. 655). It lies on the same plane, but behind the striated sphincter of the membranous urethra, and has no attachment to it. The two muscles function as the external sphincter of the urethra.

The *membranous urethra*, so-called because it has no strengthening walls, as have the prostatic and cavernous portions, is related on its deep aspect with the pubic recess or anterior prolongation of the ischiorectal fossa. It is the shortest division of the urethra, being about 1 cm. long, and is narrower than any other part save the external orifice. The membranous urethra is fixed firmly to the urogenital diaphragm by fibrous expansions dense enough to rupture it in pubic fracture. The membranous urethra lies about 2.5 cm. behind the subpubic ligament, against which it may be pressed forcibly and destroyed in a severe fall or blow upon the perineum.

Rupture of the membranous urethra occurs proximal to stricture in the cavernous portion, resulting in extravasation into the deep perineal compartment, whence exit is found only by escaping through one or the other of the fascial leaves of the diaphragm. If urine breaks through the inferior fascia, it passes into the superficial perineal pouch and forward on the abdomen in front of the pubis. If the extension is through the superior fascia, or if there is an extraperitoneal rupture of the bladder, extravasated urine enters the interval about the median puboprostatic ligaments and extends forward into the retropubic space (of Retzius). From there it ascends in the anterior abdominal wall between the transversalis fascia and parietal peritoneum.

The membranous urethra is surrounded by the *sphincter urethrae* (*external sphincter*). This striated muscle (*cf.* female, Fig. 696) is not a complete sphincter about the apex of the prostate, but does encircle the membranous urethra with a cuff of muscle 5 mm. thick. It may or may not be fused with the deep transverse perineal muscles.

The deep perineal pouch contains the *bulbourethral glands* (of Cowper) in the midst of the deep transverse perineal muscles (Fig. 660). The excretory ducts of these glands are about 2.5 cm. long. Each pea-sized gland receives a branch of the bulbourethral artery, and each duct pierces the inferior fascia of the diaphragm to open by a minute orifice on the floor of the cavernous urethra. Not infrequently these glands are involved in gonorrheal inflammation of the cavernous urethra, and may give rise to abscesses which can be felt through the rectum and evacuated through the perineum.

Between the leaves of the urogenital dia-

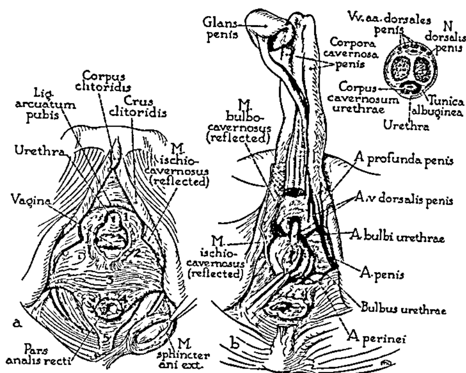


Fig. 658. ANATOMY OF THE FEMALE AND MALE PERINEUMS, ESPECIALLY OF THE DEEP PERINEAL COMPARTMENT.

In the female specimen (*a*) the sphincter muscle remains intact. The muscle fibers form a complete layer of urethral level (1) and are mergent with the intrinsic musculature of the vagina (2); they cross the perineum in the area between the vagina and the anal canal (3), and contribute to the support of the anus (4). Additionally, some fibers are prolonged dorsalward to the coccyx (5).

In the male specimen (*b*) the corpus cavernosus urethrae has been transected, the bulb retracted, and the inferior fascia of the urogenital diaphragm removed to expose the muscles and arteries in the deep perineal compartment. The muscles are the deep transverse perineal and the sphincter muscle of the membranous urethra; the arteries are the penile and its three branches: the bulbar (to the bulb of the urethra), the deep (to the crus), and the dorsal (chiefly to the glans) In the superficial perineal compartment the crus has been exposed on one side by reflection of the ischiocavernosus muscle. On the opposite half of the perineum the muscle is intact.

sac of the bulb, and strictures are likely to localize there. In the unsupported cavernous urethra, proximal to a stricture in this location, rupture is likely to occur, resulting in infiltration in the superficial perineal compartment.

The urinary extravasation, limited by Colles' fascia, first distends the posterior part of the superficial perineal pouch, then passes forward, distends the scrotum, and infiltrates the loose cellular tissue of the penis. Finally it passes upward on the anterior abdominal wall, spreading laterally behind Scarpa's fascia (Fig. 676). Urine is hindered from passing from the abdominal wall down the thighs by the attachment of Scarpa's fascia to the fascia lata.

At the posterior part of the space the *superficial transverse perineal muscles* pass medially and a little forward from their ischial origin and insert into the central part of the perineum, midway between the bulb and anus. These small muscles lie in the most posterior plane of the superficial compartment and cannot be exposed without incising Colles' fascia; they form an important landmark in perineal surgery. With the elements forming the root of the penis, these muscles help to outline a small triangular area on each side of the median line, the boundaries of which are the crus laterally, the bulb medially, and the superficial transverse perineal muscle posteriorly. The inferior fascia of the urogenital diaphragm, which extends across the space, forms the deep boundary or floor of these triangular areas (Fig. 654).

The perineum on each side of the corpus cavernosum urethrae is traversed by *vessels* and *nerves*, chiefly small branches of the pudendal trunks. The perineal artery leaves the internal pudendal in the ischiorectal fossa and runs forward toward the pubes (Fig. 654).

UROGENITAL DIAPHRAGM. The urogenital diaphragm is a semirigid musculomembranous

phragm run the *internal pudendal vessels* and the *dorsal nerve* of the *penis*. The internal pudendal artery is the terminal branch of the hypogastric artery which leaves the pelvis by the greater sciatic notch, winds about the ischial spine, and is located on the lateral wall of the ischiorectal fossa (Alcock's canal) (Fig. 654). After traversing the anal perineum, where it gives off branches to the superficial pouch, it pierces the base of the urogenital diaphragm and runs forward in the lateral part of the deep perineal pouch on the medial surface of the ischiopubic ramus (Fig. 655). Within the pouch it gives off an important artery to the bulb, which runs medially, piercing the inferior fascia of the diaphragm near the midline, and the dorsal artery of the penis. The dorsal vein of the penis runs into the prevesical (or vesical) plexus (Figs. 589, 655).

ANTERIOR PROLONGATION OF THE ISCHIORECTAL FOSSA. The anterior extension of the ischiorectal fossa is the deepest space in the anterior perineum. It runs forward toward the pubes between the superior fascia (deep layer) of the urogenital diaphragm, the anterior portion of the levator ani, and the mesial surface of the obturator internus muscle.

CENTRAL POINT OF THE PERINEUM. The central point of the perineum, a fibromuscular node lying between the anorectal junction and the apex of the prostate, serves as a point of origin for the external and internal anal sphincters and the bulbocavernosus muscle. It also is a point of insertion for the rectourethral and superficial transverse perineal muscles and for the levator fibers which support the prostate. In the female the tendinous region lies between the anorectal junction and the posterior vaginal commissure, and is termed the *perineal body*.

This area is the key region of the perineum, for it not only unites the urogenital diaphragm and anus with their common substratum, the levators, but also affords the logical perineal approach to the deeper pelvic structures.

In summarizing the chief structural differences between the anal and urogenital subdivisions of the perineum, the following features require emphasis:

In the anal portion of the perineum the ischiorectal fossa is bounded superiorly and medially by the inferior fascia of the pelvic diaphragm, laterally by the fascial covering of the obturator internus muscle, and inferiorly by the integument. However, in the urogenital portion of the perineum, above the superior

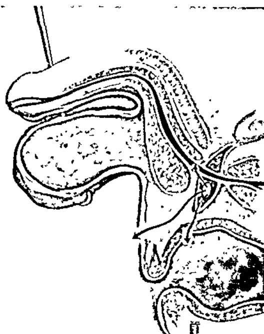


Fig. 660. POSITION OF COWPER'S GLAND BETWEEN THE LAYERS OF THE UROGENITAL DIAPHRAGM.
Arrows indicate the directions in which suppuration of the gland may evacuate into the urethra, the rectum or the perineum.
(From Bickham: Operative Surgery.)

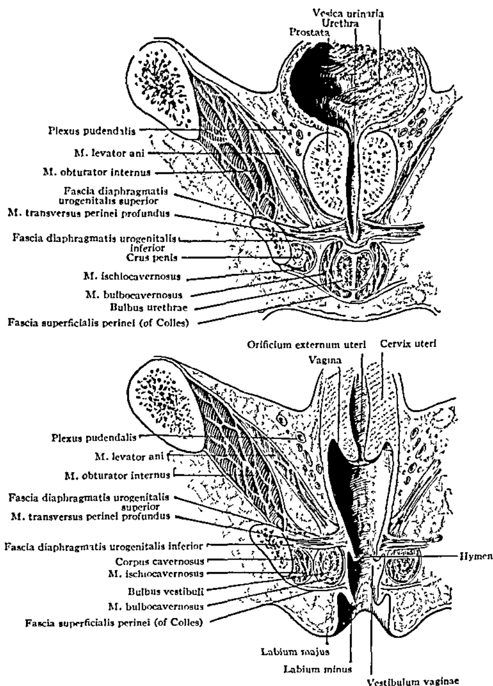


Fig. 659. UROGENITAL DIVISION OF THE PERINEUM AND RELATED PORTION OF THE PELVIS IN THE MALE AND FEMALE, SEEN IN A FRONTAL SECTION OF EACH.

then washed out with a soft rubber catheter. On some occasions a prostatic abscess can be opened with a resectoscope under vision.

Evacuation of the abscess from outside the urethra, prostatotomy, is preferable when there is no stricture of the urethra, and particularly when the abscess occupies the posterior lobe of the prostate. The membranous urethra and periurethral space are reached by careful dissection through the usual perineal prostatic incision. When the suppurating prostate is exposed, it is possible to see in which direction the abscess is pointing and to evacuate it or, if the tissues are badly damaged, to do a partial prostatectomy. Evacuation of a prostatic abscess through the posterior urethra is preferable when there is a strictured urethra. A prostatic tractor is introduced into the urethra, and a midline incision made in the perineum. The bulbous urethra is exposed and incised longitudinally upon the retractor. A finger is inserted through the urethral incision into the prostatic urethra and then through the wall of the prostatic urethra into the abscess cavity. A drainage tube is then inserted into the urethral incision to divert the urine and drain the pus.

Posterior or Anal Division of the Perineum

Definition and Boundaries. The posterior or anorectal perineum is the triangular area behind the line joining the ischial tuberosities, and is peculiarly adapted to support the terminal rectum (Fig. 653). Its base is the superficial transverse perineal musculature which lies on the posterior margin of the urogenital diaphragm; its apex, the tip of the coccyx; its lateral margins, the gluteus maximus muscles. It is subdivided into two ischiorectal fossae by the bulbo-anococcygeal raphe.

Superficial Structures. The perianal skin is thick save about the anus, where it thins out, is pigmented, moist, densely adherent to the subjacent tissue, and continuous, without demarcation, with the anal mucosa. It contains hairs and sweat glands which are the points of origin of *perianal abscesses.* The anal orifice presents folds which penetrate the anal canal, between which longitudinal excoriations (*anal fissures*) occur and produce exquisite pain. The subcutaneous tissue is in free communication with the fatty areolar tissue of the ischiorectal fossa, and within it a perianal abscess may remain localized and later open laterally or into the anal canal.

Ischiorectal Fossa. Each ischiorectal fossa or inferior pelvirectal space lies between the mesial aspect of the obturator internus muscle and the levator ani muscle (Figs. 654, 656). The *lateral wall* is vertical and is formed by the ischium and obturator internus muscle with its aponeurosis. The internal pudendal vessels and nerves are applied intimately to the wall, and their branches supply the fossae and their contents. The oblique fibers of the levator ani, as they run from the pelvis to the rectum, form the *mesial wall*, the boundary being the bulbo-anococcygeal raphe. In the course of an extensive ischiorectal abscess this musculofibrous barrier may be broken down and the infection be spread to the opposite fossa, resulting in a large horseshoe-shaped abscess, embracing, in whole or in part, the anal portion of the rectum. In the midline is the external sphincter, which surrounds the anal canal. The gluteus maximus muscle and sacrotuberous ligament form the *posterior wall.* The superficial transverse perineal muscles and free margin of the urogenital diaphragm mark out the *anterior boundary* of the region superficially. The fossa is related to the extraperitoneal cellular space of the pelvis (superior pelvirectal space) through the levator ani and its enveloping aponeuroses. An ischiorectal abscess may perforate the levator ani and gain access to this space. More frequently a large abscess in the ischiorectal fossa pushes the levator upward against the rectum, obliterating the extraperitoneal space so that the abscess ulcerates into the rectum without seriously contaminating the pelvic spaces.

There are two important pouches in each fossa (Fig. 662). An *anterior prolongation* or *pubic recess* (p. 695) continues the fossa forward. It is a wedgelike interval between the forward portion of the obturator internus muscle and the superior fascia of the urogenital diaphragm. A *posterolateral prolongation* lies between the levator ani and gluteus maximus muscles.

The obturator internus and inferior levator ani fasciae line the walls of the fossa. These, with the superior fascia of the levator, constitute the two divisions of the pelvic fascia which diverge from their origin at the tendinous arch (Fig. 659).

Contents of the Fossa. The *ischiorectal fat*

fascia of the urogenital diaphragm on either side, the fat-filled ischiorectal fossa extends forward to the anterior limit of the perineum (Fig. 659). The lateral boundary of the space is still formed by the parietal fascia covering the obturator internus muscle, the superior boundary by the fascia which covers the under surface of the levator ani muscle; however, the inferior boundary is the fascia, likewise diaphragmatic, on the upper surface of the urethral sphincter. This means that, whereas the fatty superficial fascia of the ischiorectal fossa in the anal region is the only layer between the skin below and the fascia of the pelvic floor above, a complex series of additional layers (related to two compartments) intervene between integument and diaphragmatic fascia in the urogenital division of the perineum. In other words, in the urogenital triangle a series of important additional strata intervene between the integument and the inferior fascia of the pelvic diaphragm. These layers are the deep membranous layer of the superficial fascia, the erectile tissue and the muscles of the superficial perineal compartment; the superior fascia of the urogenital diaphragm; the fatty tissue in the anterior recess of the ischiorectal fossa. Were these strata not present, the succession of layers in the two subdivisions of the perineum (anal and urogenital) would be similar and, moreover, comparable to that obtaining over the body generally, namely, the integument, the fatty pannicle and the deep fascial investment of the muscle the anal triangle the diaphragmatic fascial l on the under surface of the levator ani m is the third reached as the dissector w inward; in the urogenital triangle the s layer is the ninth stratum encountered.

Surgical Considerations

Perineal Approaches for Drainag Periprostatic and Prostatic Absc Intraprostatic abscess is one of the resul acute prostatitis (p. 623). Periprostatic scesses are found in the immediate vicini the prostate (Fig. 661). Abscesses about prostate localize most frequently in the anterior to the rectum, and are likely to ru into the rectum or the membranous ure or upon the perineum. Those lying later the gland tend to invade the ischiorectal fo while those superior to the prostate ten localize between the seminal vesicles.

The most satisfactory method of evacu a prostatic abscess is by surgical evacu through the perineum, either by exposu the prostate or by external urethrotom circumstances may dictate. The transure route is occasionally used. With the pa under deep anesthesia, whether spinal, ca or deep inhalation anesthesia, a sound is pa into the posterior urethra and, with a fing the rectum, is rotated from side to side so enter the abscess cavity. The pus evacu into the posterior urethra and bladder an

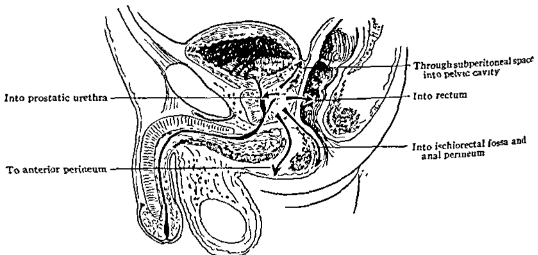


Fig. 661. PATHS OF EXTENSION FROM PROSTATIC ABSCESS.

The abscess may extend through the subperitoneal space into the pelvic cavity; into the rectum; into the ischiorectal and anal perineum; into the prostatic urethra.

fat and external anal sphincter. The perineal artery branches from the internal pudendal in the anterior part of the region to supply portions of the anterior perineum.

ANAL PORTION OF THE RECTUM. The anal canal, about 4 cm. in length, passes downward and backward to connect the rectal ampulla with the exterior. The sides of the canal are related to the fat pads of the ischiorectal fossa and are liable to involvement in any infection in the fossa. Anteriorly, the anal canal is related to the central tendinous point of the perineum, the membranous part of the urethra, and the bulb. Advantage is taken of these relations in passing an instrument through a difficult stricture of the urethra. With a forefinger in the rectal ampulla, the beak of the entering instrument can be controlled and prevented from making a false passage.

The ANAL CANAL presents four landmarks: (1) the anocutaneous line (anal verge or rima); (2) Hilton's line (palpable more than visible); (3) the pectinate (dentate) line; and (4) the anorectal line.

The *anocutaneous line* marks the lower end of the gastrointestinal tract. It is the external margin of the walls of the anus in its normal state of apposition. The epithelium superior to this line usually is thrown into folds by the action of an involuntary muscle, sometimes termed the "corrugator of the anal skin."

Hilton's white line in the living subject is decidedly blue and is palpable rather than visible. It marks the linear interval between the internal and external sphincters. This interval lies halfway between the anal verge and the pectinate line.

The band of tissue between the intersphincteric space and the pectinate line has a smooth surface and a glossy, shining appearance. It may be likened to a circular sawblade whose teeth point upward. These dentations interdigitate with the rectal columns of Morgagni to form the anal papillae. The appearance of this area with its dentations led Stroud to call this region the *pecten* from its resemblance to a comb (Latin, *pecten*). Miles emphasizes the significance of the pecten by describing the heavy deposit of fibrous tissue underlying it as the pathologic result of inflammation, "pectenosis." He believes that it is necessary to cut this stenosing ring of fibrous tissue (pectenotomy) to cure anal fissure. The pecten is an important anatomic and clinical landmark. It is the mucocutaneous junction, and is the divide over which prolapsing masses of mucosa fall through the sphincter region. Immediately proximal to this area lies the internal hemorrhoidal ring, where internal hemorrhoids develop. Caudal to this line, external hemorrhoids develop. The pecten also is the lymphatic watershed of this region. The mucous membrane and bowel above this line drain into pelvic lymph nodes. The skin distal to this line drains into the subinguinal glands by lymphatics which run around the root of the thigh. The territories of the cerebrospinal and the sympathetic nerves also meet here.

The *anorectal line* lies about 1.5 cm. proximal to the pectinate line, and between the two are the columns and crypts of Morgagni. The anorectal junction, so formed, lies 1½ inches proximal to the anocutaneous line when the canal is empty.

The muscles of the anal canal are developed strongly into SPHINCTERS. The circular muscle fibers of the rectum are continued downward to form the *internal sphincter*, which encloses the upper two thirds of the canal. The fibers constituting the *external sphincter* are attached to the tip of the coccyx and the anococcygeal raphe behind the central point of the perineum. When the anal canal is obliterated, i.e., its muscles in a state of contraction, much of the external sphincter lies distal to the internal, definitely overlapping it. When the canal is distended by digital examination or by the passage of a formed stool, the sphincters occupy a more truly internal and external position. Even then the lower margin of the internal sphincter is definitely proximal to the lower margin of the external sphincter. The external sphincter can be palpated easily as a definite roll of muscular tissue. The *mucosa* is attached loosely to the muscle walls, particularly in the upper part, where it is disposed in a number of vertical folds, the rectal columns of Morgagani. At their lower ends these columns are united by semilunar folds, the anal valves. An anal fissure is produced by the tearing downward of one of the anal valves by a hard fecal mass.

BLOOD VESSELS AND LYMPHATICS. The main ARTERIAL SUPPLY to the anal canal is from the inferior hemorrhoidal arteries, branches from the internal pudendal (Fig. 656). The superior, middle and inferior hemorrhoidal *veins* form an internal hemorrhoidal plexus in the sub-

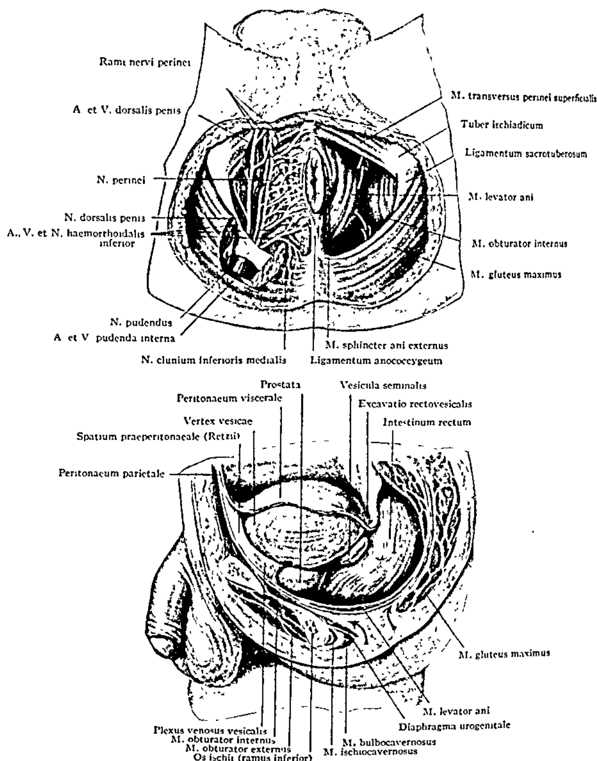


Fig. 662. BOUNDARIES, CONTENTS AND PROLONGATIONS OF THE ISCHIORECTAL FOSSA.
Above, Main space of the fossa, and its anterior and posterior recesses (indicated by arrows), seen from the inferior aspect. *Below*, Fossa and prolongations (again indicated by arrows), viewed in a paramedian section.

is abundant and is loculated by fibrous septa derived from the inferior levator fascia. Like the fat in the orbit, it persists in patients who otherwise are emaciated. It is destroyed rapidly in suppuration and is reproduced slowly. The yielding character of the fat readily permits the dilation of the rectum at defecation.

Before the *internal pudendal artery* and *nerve* penetrate the urogenital diaphragm, they are applied by a duplication of fascia (Alcock's canal) against the obturator internus aponeurosis (Figs. 656, 662). Inferior hemorrhoidal branches leave the parent trunks within the fossa and are distributed to the ischiorectal

The membranous urethra, prostate, seminal vesicles and vasa deferentia can be exposed much more readily if the region about the neck of the bladder be levered into the wound by Young's intravesical retractor.

ANAL ABSCESS AND ANAL FISTULA. These two subjects are considered together because of the role of anal abscess in the formation of anal fistula. Any of the pyogenic organisms which inhabit the colon are capable of producing inflammatory changes which may terminate with the formation of an abscess. Occasionally the *Mycobacterium tuberculosis* is responsible and follows the same course of events (Fig. 663), leading to a fistula in ano, as prevails for the more common organisms. Instead of using the terms "internal" or "external" as applied to the openings of an anal fistula, it is preferable to apply the terms "primary" and "secondary" openings. Thus, since an anal fistula has its point of origin in an anal crypt, its primary opening should be found at the dentate margin. It follows readily that any and all other openings of a fistula are secondary and may be variously placed as a consequence of the direction the infection takes and the location of the abscess (Fig. 664).

For the location and pathways of anal fistulae, *Goodsall's rule* (Fig. 665) is worth knowing. Nesselrod believes that the direction of lymphatic drainage from the anal, perianal and perineal tissues explains the rule.

The treatment of an anal abscess is early incision and drainage, before the infection spreads. Superficial (ischorectal) abscesses are opened through the overlying softened tissues. The closer the incision is made to the anal margin, the shorter will be the resultant fistulous tract. Supralevator or deep abscesses should be drained through a para-anal approach.

The principles in the surgical treatment of anal fistula as set forth by Buie are as follows (Fig. 666): (1) The primary opening must be

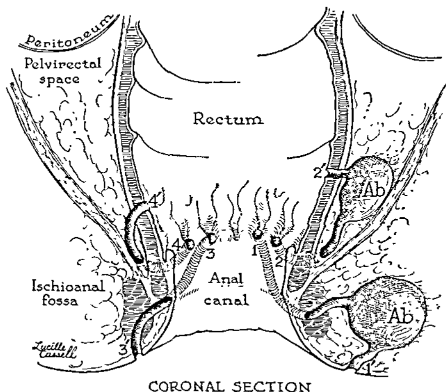


Fig. 664. COMMON LOCATIONS OF ANAL ABSCESSES AND FISTULOUS OPENINGS.

The infralevator spaces (ischiorectal fossae) are much more commonly involved than the pelvirectal (supralevator) spaces. From the latter an abscess may extend through the intervening pelvic diaphragm to the lower ischio-anal space. A supralevator abscess may drain spontaneously into the rectum, as at 2'. Subsequent shrinkage of the abscess leads to a chronic fistulous process similar to the tract from 4 to 4'. Occasionally an abscess will drain through its primary opening, and is then a sinus. An ordinary anal fistula is 3 to 3'. 1, 2, 3 and 4 are primary openings; 1', 2', 3' and 4' are secondary openings. (From Nesselrod: Proctology in General Practice.)

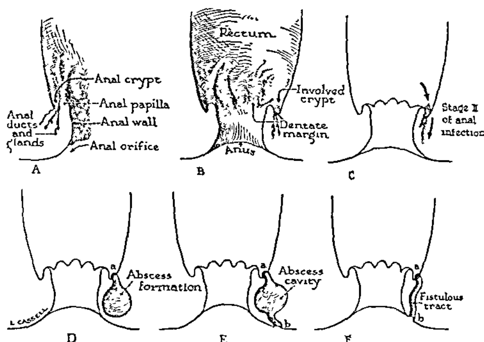


Fig. 663. DIAGRAMMATIC REPRESENTATION OF THE PATHOGENESIS OF ANAL FISTULA.

A, Infected material from the bowel invades one or more of the anal crypts and the tiny vestigial anal glands. This "primary" process is at the dentate line. *B* and *C*, The infection spreads to the perianal and perirectal tissue indirectly by way of the lymphatics or directly by breaks in the continuity of the gland duct structure. *D*, Abscess formation. *E*, The abscess spontaneously ruptures or is incised on the perianal skin surface, and the fistulous tract is complete. The skin opening is a "secondary" opening. If the abscess had drained into the rectum, the secondary opening would have been at that point. *F*, Collapse of the abscess leaves the commonly seen narrow fistulous tract. (From Nesselrod: Proctology in General Practice)

mucous and subcutaneous tissues of the anal canal. This plexus presents a distinct band of dilated veins, forming what is termed the hemorrhoidal ring. Minute clusters of thin-walled veins comprising the ring lie within the columns of Morgagni. In the recesses between the columns is what is known as the hemorrhoidal zone. The superior hemorrhoidal veins pierce the muscle coat to unite in the sigmoid mesocolon in a common trunk tributary to the inferior mesenteric vein. The middle hemorrhoidal veins empty into the hypogastric (internal iliac) vein, and the inferior hemorrhoidal veins join the internal pudendal vein.

The LYMPHATICS of the rectum and anal canal have a plexiform arrangement in the mucous and submucous coats. Those located above the mucocutaneous line drain into lymph nodes lying on the posterior surface of the rectum, and their efferents ascend along the superior hemorrhoidal artery to end in the sacral and lumbar lymph nodes (Fig. 593). The lymph vessels from the lower part of the canal pass to the medial group of the subinguinal nodes, whence efferent trunks pass through the femoral ring to empty into the external iliac lymph nodes.

Surgical Considerations

TRANSPERINEAL APPROACH TO THE MEMBRANOUS (DEEP) URETHRA, PROSTATE AND SEMINAL VESICLES. An exaggerated lithotomy position with the perineum parallel to the floor is the ideal position in all operations on the membranous (deep) urethra, prostate and seminal vesicles, the purpose being to keep all tissues on tension, so that with each cut the exposure is increased. It is vital that the rectourethralis muscle be kept tense.

A sound introduced into the bladder serves as a guide, and a curved incision with a forward convexity is made about 2.5 cm. anterior to the anus. By blunt dissection the anterior prolongations of the ischiorectal fossa are opened, so that, with a finger in each, the sound in the urethra can be felt between them. With bifid retractors the transverse perineal muscles and bulb are pulled upward and the rectum downward in order to put the *central tendon* under tension. As the central tendon is cut, the rectourethral muscle presents and in turn is severed. If tension on the rectourethral muscle is relaxed, there is danger of entering the rectum.

found. (2) The fistulous tract or tracts must be traced. (3) Structures external to the primary opening and the fistulous tracts must be cut away *so that the fistulous tunnels are converted into open ditches throughout their course.* (4) Measures must be adopted during and after the operation to ensure that the cavity will heal from within outward, without development of further tracts.

HEMORRHOIDS. Hemorrhoids, or piles, are varicosities or dilatations of the veins of the anal canal (Fig. 667). Those arising from the radicles of the middle hemorrhoidal vein, usually the anterior or right and left groups, are situated in the lower rectum and upper anal canal above the external sphincter in the area occupied by the columns of Morgagni. They are called *internal hemorrhoids* to distinguish them from the dilatations of the plexuses of the inferior hemorrhoidal veins which are covered with skin; these are called *external hemorrhoids* (Fig. 668).

Digital examination for internal hemorrhoids may reveal only thickened folds of mucous membrane, but proctoscopic examination reveals three to five bluish-red longitudinal folds. When internal hemorrhoids become large, they sometimes are carried through the anus in defecation and become extremely painful. They may be so constricted by the external sphincter as to present areas of sloughing and gangrene. Bleeding from the eroded surface of such veins is common and is likely to produce a severe anemia. Pain may be relieved by returning the everted varicositief through the anal orifice, but permanent relies is obtained only by their removal. The methodf available for this purpose are injection os sclerosing chemicals, excision (Figs. 669, 670), and clamping with cauterization.

External hemorrhoids usually are not painful unless they undergo thrombosis. If thrombosed, and particularly if infected, they form hard, painful, circumscribed tumors which require incision and evacuation.

FISSURE IN ANO. This is one of the most painful lesions of the anal canal, the acute distress coming on with and following defecation. The fissure appears to be a longitudinal crack in the anal skin, but really is a true ulcer (Fig. 671). It usually begins a short distance distal to the dentate line and ends about the anal verge. The common site is the posterior anal wall in both sexes; the next most common is the anterior anal wall, especially in females.

A considerable degree of inflammation is usually present about the fissure, and, since this area is sensitive, pain is an outstanding complaint. The distal end of the ulcer tends to form a pocket which collects irritating fecal discharge and secretions. Careful probing at the time of operation frequently shows an anal crypt underlying the proximal portion of the fissure and a small subcutaneous pocket at its distal margin. Treatment consists in wide excision of the ulcer with exteriorization of the

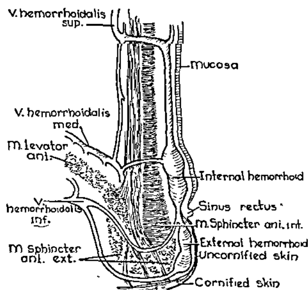


Fig. 667. HEMORRHOIDAL VEINS, SHOWING INTERNAL AND EXTERNAL HEMORRHOIDS.
(R. I. Hiller.)

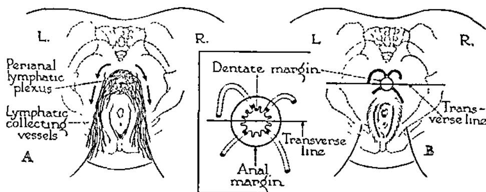


Fig. 665. PERIANAL LYMPHATIC DRAINAGE AND GOODSALL'S RULE.

A, Direction of perianal lymphatic plexus. *B*, Goodsall's rule: Fistulae with an external (secondary) opening situated posterior to an imaginary line passing transversely through the center of the anus usually have the internal (primary) opening in the midline and posteriorly, so that the tract is curved. When the external (secondary) opening is anterior to the transverse line, the internal (primary) opening is immediately opposite; hence the tract is straight. (From Nesselrod: Clinical Proctology.)

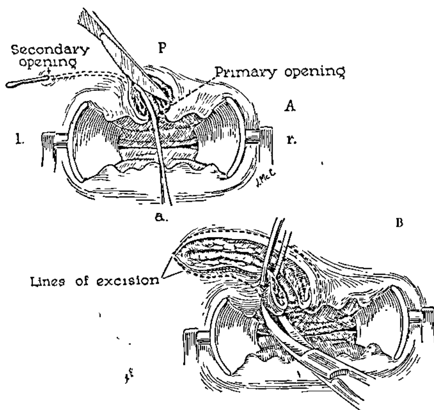


Fig. 666. FISTULOTOMY.

A, Fistula with a secondary opening in the posterior half of the perianal area has a primary opening in the midline posteriorly (Goodsall's rule, Fig. 665). A probe lying within the fistula is being freed by incision of the overlying tissue. *B*, Excision of the overhanging skin margins converts the fistulous tunnel into an open ditch, so that the tract will heal from within outward. (From Nesselrod: Clinical Proctology.)

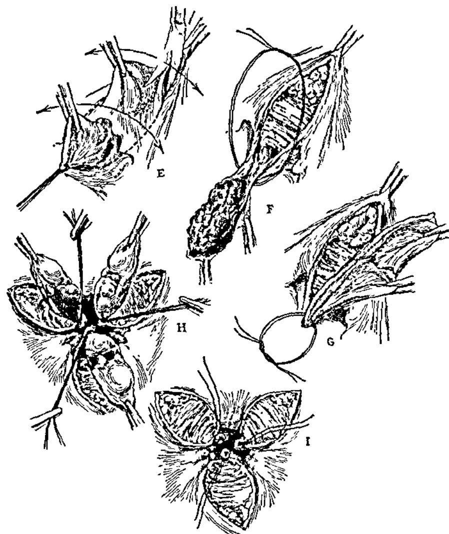


Fig. 670. LIGATURE EXCISION TYPE OF OPERATION FOR HEMORRHOIDS (CONTINUED).

E, Incisions indicated by broken lines. *F*, Dissection completed; ligation begun. *G*, Hemorrhoidal mass doubly ligated. *H*, Each hemorrhoidal mass dissected and doubly ligated *I*, Hemorrhoidal masses amputated, leaving hemorrhoidal stumps; operation completed except for excision and the trimming of the cutaneous isthmuses which separate the wounds.

Postoperatively, when the anal sphincters regain their tone, the wound edges are drawn close together, and edema of the tissues may be sufficient to cause actual apposition of the skin edges. (From Nesselrod: *Clinical Proctology.*)

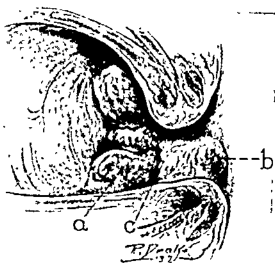


Fig. 668. GROSS DISTINCTION BETWEEN INTERNAL AND EXTERNAL HEMORRHOIDS.

a, Internal hemorrhoid covered by mucous membrane; *b*, external hemorrhoid covered by skin; *c*, pectinate line separating two types of hemorrhoids. (Buie.)

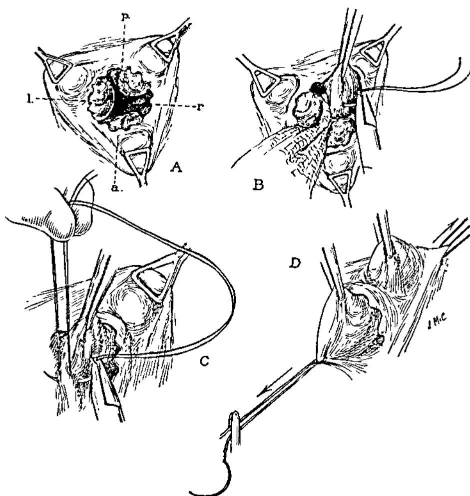


Fig. 669. LIGATURE EXCISION TYPE OF OPERATION FOR HEMORRHOIDS.

A, Retraction of anal margins by means of triangular forceps. *B*, First passage of needle carrying the suture-ligature *C*, Second passage of needle carrying the suture-ligature. *D*, Suture-ligature proximal to internal hemorrhoid, and Kocher forceps distal to external hemorrhoid; hemorrhoidal mass controlled by 2 or more Kocher forceps in the surgeon's left hand. (From Nesselrod: Clinical Proctology.)

underlying anal crypts and sinuses, so that a smooth ditch leads from just above the dentate line well out onto the perianal skin. The tract then should heal from within outward.

RECTAL PROLAPSE AND INTUSSUSCEPTION. Rectal prolapse is the protrusion of part or the entire thickness of the rectal wall through the anal orifice (Fig. 672). In an *incomplete* or *partial prolapse* the mucous membrane of the perineal or anal part of the rectum protrudes from the anus and fails to retract when defecation ceases. The loose connection between the mucous membrane and muscular coat of the bowel facilitates this form of prolapse. The everted mucosa remains protruded because the relaxed submucosa is unable to draw it back through the canal against the obstructing action of the sphincters. This is exemplified by the prolapse occasionally seen with hemorrhoids, which, because of their size and the traction they exert on the mucous membrane, show a marked tendency to descend and protrude through the anus. Reduction is spontaneous for a time, but becomes increasingly difficult. The prolapsed part usually is of limited extent, and may involve but a part of the anal circumference.

Partial prolapse is common in early childhood, when the pelvic rectum is straighter, more vertical and much more movable than in the adult, since it lacks the support from the fully developed pelvic organs. Prolapse occurs in adults, particularly in old age, when the muscle tone of the bowel is weakened. It occurs fairly commonly with urethral stricture, enlarged prostate and chronic bronchitis, in all of which there is a sudden and frequently recurrent increase in intra-abdominal pressure.

The comparative rarity of *complete prolapse* is accounted for by the secure manner in which the rectum is held in position. Weakening of the pelvic floor and anal sphincter, or relaxation of the rectal suspensory apparatus, including the pelvic mesocolon and its contained vessels, are predisposing causes.

The prolapsed part consists of two concentric cylinders, the outer of which is continuous above with the anal skin. The inner or enclosed cylinder ascends within it through the anus into the pelvis, where it is continuous with the pelvic colon. When a complete prolapse attains large dimensions, the peritoneum of the rectovesical or rectovaginal pouch descends and forms a distinct cul-de-sac anteriorly between the inner and outer cylinders. Into this pouch a loop of small intestine or piece of omentum may find its way and become incarcerated, causing a sudden or marked increase in the size of the prolapsed part. A peritoneal pouch is not formed posteriorly, since the pelvic mesocolon and contained vessels descend but to a limited extent. The prolapse may assume a decided backward curve because of the resistance these structures offer to a descent of the bowel.

Prolapse may be associated with *intussusception*, wherein the invagination of some higher part of the rectum into the immediately adjoining segment below emerges through the anus (*cf.* Fig. 510). Intussusception originating in the colon or even in the cecal segment may present through the anus in a similar manner. In true prolapse the base of the outer cylinder is always continuous with the skin. In intussusception there is a slitlike interval all around between the intussuscepted part and the anal mucous membrane.

PILONIDAL SINUSES AND CYSTS. These structures are common congenital anomalies consisting of stratified squamous epithelium-lined

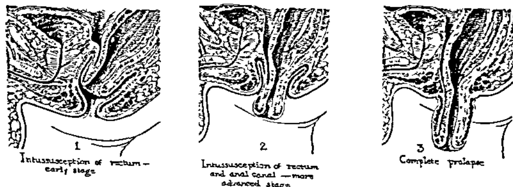


Fig. 672. VARIETIES OF RECTAL INTUSSUSCEPTION AND PROLAPSE.

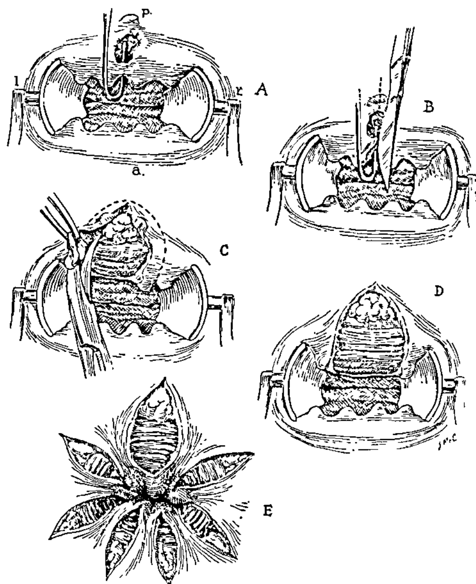


Fig. 671. EXCISION OF POSTERIOR ANAL CRYPT, AND PERFORMANCE OF MULTIPLE CRYPTOTOMY.

A, Fissure, with probe in the proximal anal crypt and distal subcutaneous pocket. *B*, Excision of the fissure with a section of underlying scar tissue. *C*, Excision of overhanging margins and enlarged anal papillae. *D*, Excision completed to shallow trough shape; sphincter muscle at base. *E*, As commonly needed because of further inflammatory disease, the remaining anal crypts have been probed and, if enlarged, are exteriorized, and the remaining anal papillae have been excised (From Nesselrod: Clinical Proctology.)

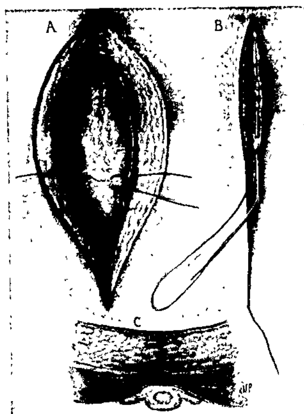


Fig. 674. EXCISION OF PILONIDAL SINUS, AND PRIMARY CLOSURE (CONTINUED).

A, Midline closure of previously cut musculofascial gluteal flaps. Note how the suture takes a bite of presacral fascia to ensure obliteration of dead space. *B*, Continuous subcuticular suture of dermol or steel approximates the skin. The posterior 2 cm. of the wound is left open for the drainage of blood and serum. *C*, Midline approximation of all layers, with dead space obliterated. (From Holman: Surg., Gynec. & Obst., 83: 94-100, 1946.)

no genital lesion, external or internal, has been demonstrated, is not so clear. Extension of the disease from the male anterior urethra to the posterior urethra eventually may involve the rectal lymphatics and cause stricture. In most of the cases of rectal stricture in the male, abnormal practices (pederasty) account for the direct implantation of the virus into the rectal mucosa.

A primary anal lesion may spread to the rectum by way of the anorectal lymphatics. The end-result of this invasion is perirectal fibrosis, with subsequent development of stricture of the rectum.

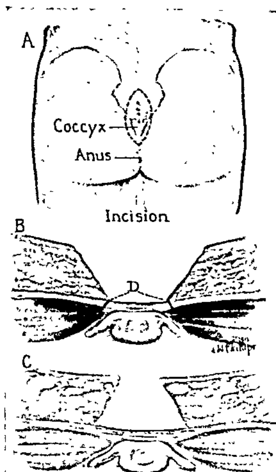


Fig. 673. EXCISION OF PILONIDAL SINUS, AND PRIMARY CLOSURE.

A, Elliptical incision through the skin and subcutaneous tissue surrounding the sinus openings. *B*, The incisions should slant medially, and not laterally as in *C*, in order to avoid undermining the skin with formation of an uncollapsible dead space over the coccyx and lower sacrum. *D*, The gluteal fascia incised and mobilized to permit approximation in the midline. (From Holman: Surg., Gynec. & Obst., 83: 94–100, 1946.)

pockets sometimes containing hair, and occurring in the soft tissues overlying the sacrococcygeal hiatus. One or more small skin openings may be present, but the condition is *usually not recognized until infection occurs*, when it may assume considerable proportions and present redness, tenderness and swelling. With incision or spontaneous drainage the inflammation subsides, only to recur later. As a point for differentiation, the true pilonidal sinus runs cephalad, while the *sacrococcygeal dimple sinus* runs caudad.

Treatment of this condition is always surgical. While excision of the sinus appears to be an easy matter, to obtain permanent cure is not so easy. Unless entirely removed, the sinuses will recur. For the acute abscess phase, incision and drainage are needed. Two or three months later, surgical cure is indicated by complete eradication of the sinus, its cystic counterparts and accessory sinuses. The number of procedures advocated to accomplish this are multitudinous, all because failures are common. Three main attacks can be considered: (1) opening of the sinus and allowing the wound to granulate and heal over; (2) the use of sclerosing fluids injected into the sinus tract; (3) complete surgical excision of the whole process with primary closure of the wound. *The last is preferable (Figs. 673, 674).*

Anomalies of the Lower Rectum and Anal Canal. A description and explanation of the commoner congenital malformations of the lower rectum and anal canal are given in the section on the Pelvic Rectum.

Lymphopathia Venereum (Lymphogranuloma Inguinale). Lymphopathia venereum is usually characterized in the acute stage by mild febrile reaction, and by an inguinal adenitis which follows a minute, evanescent and often unnoticed primary lesion. The inguinal nodes break down soon, and one or more chronic, draining sinuses result. The anus and rectum are often involved primarily or secondarily, and the commonest lesion is inflammatory rectal stricture. Surgical anatomic interest in rectal involvement in this disease lies in the lymphatic paths of extension between the external and internal genitalia and the rectum.

If the initial lesion occurs at any point on the external genitals of either sex, regional inguinal adenitis (bubo) usually results from a direct spread of infection. Inguinal involvement is more common in the male, because external genital lesions are the rule, and the lymphatic extension is direct. Rectal stricture is the usual secondary manifestation in the female, because the initial lesion commonly is *at some point along* the posterior vaginal wall or on the cervix, implanted there from the lesion on the male external genital. Lymphatic drainage from these areas traverses the uterosacral ligaments which skirt the lateral walls of the rectum. The rectal lymphatics are then involved by direct anastomosis. A more direct invasion of the rectal lymphatics leading to rectal stricture is by way of the lymph vessels of the rectovaginal septum.

Explanation of the frequent involvement of the rectum in the male, and of the occasional involvement of the rectum in the female when

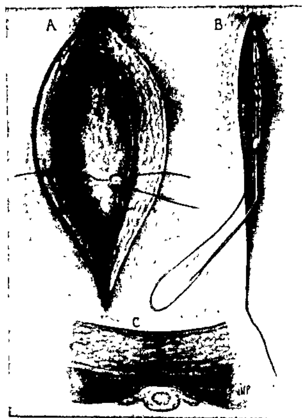


Fig. 674. EXCISION OF PILONIDAL SINUS, AND PRIMARY CLOSURE (CONTINUED).

A, Midline closure of previously cut musculofascial gluteal flaps. Note how the suture takes a bite of presacral fascia to ensure obliteration of dead space. *B*, Continuous subcuticular suture of dermol or steel approximates the skin. The posterior 2 cm. of the wound is left open for the drainage of blood and serum. C, Midline approximation of all layers, with dead space obliterated. (From Holman: Surg., Gynec. & Obst, 83: 94–100, 1946.)

no genital lesion, external or internal, has been demonstrated, is not so clear. Extension of the disease from the male anterior urethra to the posterior urethra eventually may involve the rectal lymphatics and cause stricture. In most of the cases of rectal stricture in the male, abnormal practices (pederasty) account for the direct implantation of the virus into the rectal mucosa.

A primary anal lesion may spread to the rectum by way of the anorectal lymphatics. The end-result of this invasion is perirectal fibrosis, with subsequent development of stricture of the rectum.

CHAPTER 22

External Genitals

Penis

DEFINITION AND DIVISION. The penis is composed of a posterior fixed part, or root (Figs. 657, *b*; 658, *b*) and an anterior mobile part, or body (Fig. 675).

The *body* of the *penis*, formed by the union of the cavernous bodies, begins at the apex of the urogenital diaphragm beneath the pubic angle, and is attached firmly to it by connective tissue bands. The corpora cavernosa of the penis lie side by side on the dorsum, and the corpus cavernosum of the urethra lies in the ventral groove (Figs. 675, 678). The corpus cavernosum urethrae at its anterior termination expands into a conical enlargement, the *glans penis*, which spreads out as a cap over the blunt anterior extremities of the corpora cavernosa of the penis. The posterior part of the corpus cavernosum urethrae terminates posteriorly in a large, free, bulbous extremity, the *bulb* of the *urethra*. This considerably overlaps the junction of the membranous and cavernous divisions of the urethra posteriorly. The promi-

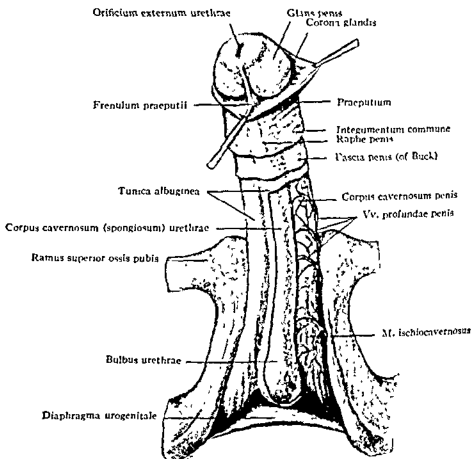


Fig. 675. STRUCTURE OF THE PENIS, AND ITS RELATION TO THE SYMPHYSIS PUBIS.

nent margin of the glans, the *corona*, projects dorsally and laterally beyond the extremities of the corpora cavernosa penis.

SUPERFICIAL STRUCTURES. The skin of the penis is thin, loose, free from hair, and freely movable over the body of the organ. At its neck, the skin is folded back to form a cuff or hood, the *prepuce* or covering for the glans. Within the cavity of the prepuce the modified skin contains the sebaceous glands secreting the smegma. Since this secretion is an admirable culture medium for microorganisms whose normal habitat is the preputial cavity, there often occurs about the corona of the glans a more or less active inflammation of the apposed surfaces of the glans and prepuce (balanoposthitis).

This infection may establish adhesions between the prepuce and glans and obliterate the preputial cavity. On the under aspect of the glans a well marked fold of skin, the *frenum*, passes forward and is attached to the prepuce.

The *subcutaneous tissue* in the penis is loose in texture, devoid of fat, and traversed by the

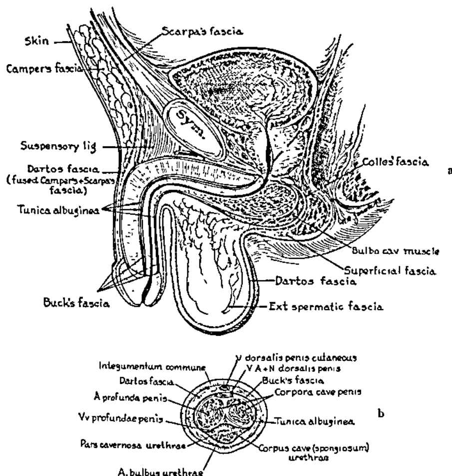


Fig. 676. FASCIAE IN PENILE URINARY EXTRAVASATION.

Camper's and Scarpa's fasciae of the anterior or abdominal wall fuse to form the dartos fascia of the penis and scrotum. The dartos fascia is continuous with the subcutaneous fatty layer and with Colles' fascia of the urogenital triangle. Buck's fascia is external to the bulbocavernosus muscle and to the tunica albuginea of the 3 vascular components of the penis. *b*, Cross section of the shaft of the penis shows the relation of Buck's fascia to the dorsal vessel and nerves of the penis; the tunica albuginea of the erectile bodies of the penis; and the compartment formed by Buck's fascia around the corpus spongiosum.

The course of urinary extravasation from rupture of the penile urethra passes first through the corpus spongiosum (where it enters the vascular, erectile tissue) and the tunica albuginea of the corpus spongiosum. Since Buck's fascia limits further spread, the extravasation may cause filling and distention of this compartment formed around the corpus spongiosum. After perforating Buck's fascia, the spread is between Buck's and Colles' fasciae in the perineum; between Buck's and dartos fasciae around the penis; between the dartos and the external spermatic fasciae in the scrotum; and between Scarpa's fascia and the deep fascia over the aponeurosis of the external oblique muscle over the abdomen. (From Tobin and Benjamin: Surg., Gynec. & Obst., 77: 195–204, 1944.)

CHAPTER 22

External Genitals

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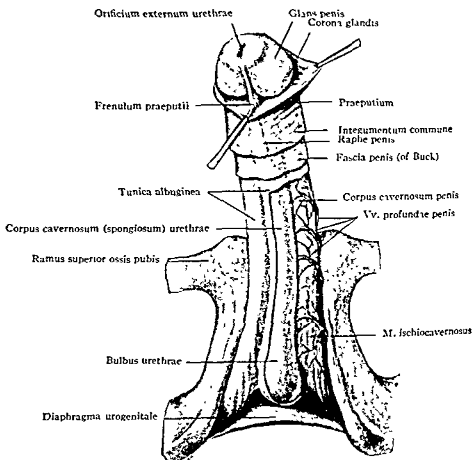


Fig. 675. STRUCTURE OF THE PENIS, AND ITS RELATION TO THE SYMPHYSIS PUBIS.

corpora of the penis, deep to the fascia and lateral to the deep dorsal vein. The cavernous arteries penetrate the corpora of the penis at their posterior extremities and run axially postero-anteriorly.

The *veins* returning the blood from the erectile tissue lie deep to the fascia and empty mainly into the deep dorsal vein.

The penile *lymphatics* are collected into two main groups, an extensive one from the glans, and a network from the skin (Fig. 679). Both these groups empty into large lymphatic trunks which follow the dorsal vein of the penis and, at the root of the organ, pass to the inguinal and iliac lymph nodes. The group of lymphatics from the skin empties into the superficial subinguinal nodes, while the group from the glans passes to the deep subinguinal nodes and thence to the external iliac lymph nodes through the femoral canal. Since the glans is the most frequent site of penile malignancy, it is of the greatest importance that, along with amputation of the penis, the deep femoral and iliac nodes be extirpated as well as the superficial inguinal nodes (Fig. 685). It is well to remember also that, although the lymphatic drainage of the penis is primarily inguinal, the pelvic nodes may be invaded directly, without involvement of the inguinal nodes, owing to the direct communication of the lymphatics of the deep urethral and dorsal vein with the iliac vessels.

Cavernous Urethra. The cavernous division of the urethra, about 18 to 20 cm. long, is by far the longest portion, and extends from the inferior or superficial layer of the urogenital diaphragm to the external meatus (Fig. 680; *cf.* Fig. 659). After piercing the urogenital diaphragm the urethra enters the bulb about 1 cm. in front of its rounded posterior extremity (Fig. 656). In traversing the cavernous body of the urethra, the urethra lies nearer the dorsal than the ventral aspect (Fig. 678). The bulbous portion of the urethra usually is capacious and forms the most dependent part of the perineal curve. The *bulbourethral glands* (of Cowper) open into the urethra at its lower or posterior wall. The external orifice is the narrowest part of the canal and may require incision to permit the passage of instruments, which then pass readily through the remainder of the canal.

Strictures may occur at any point in the cavernous urethra; when several are present, the one first encountered must be dilated to full size before the next is dealt with. The passage of a sound along a normal urethra into the bladder presents no difficulty if the beak is kept in contact with the roof of the urethra after the navicular fossa has been passed. It then will find its way more readily into the

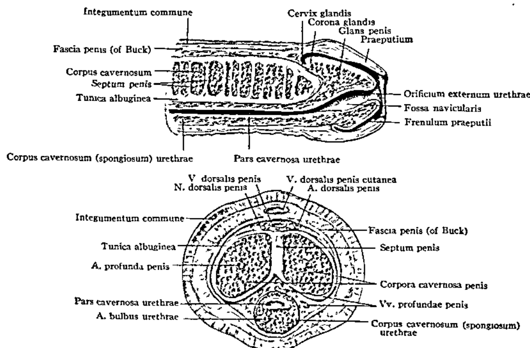


Fig. 678. SAGITTAL AND CROSS SECTIONS THROUGH THE ANTERIOR PART OF THE URETHRA.

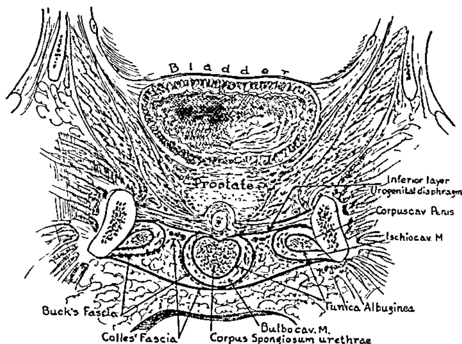


Fig. 677. FASCIAE IN PENILE URINARY EXTRAVASATION (CONTINUED).

Buck's fascia forms 3 separate compartments around the erectile bodies and their muscles in the urogenital triangle of the perineum. Colles' fascia is superficial to Buck's fascia. The normal position of Colles' fascia is shown by the dotted line, whereas its position in extravasation is shown by the solid line. (From Tobin and Benjamin: Surg., Gynec. & Obst., 79 195–204, 1944.)

superficial dorsal vein. The laxness of this tissue gives mobility to the penis and explains the urinary and bloody extravasations producing enormous distention in the organ. The *superficial lymphatics* accompany the superficial dorsal vein and enter the subinguinal nodes. They are involved in infection about the prepuce and glans and form tender, hard knots over the dorsum of the organ. Beneath the subcutaneous layer the penis is invested by a thin, fibrous membrane, the *fascia* of the *penis* (*Buck's fascia*), which extends anteriorly to the free margin of the prepuce and is continued backward in the perineum to the posterior margin of the triangular ligament. This fascia is important in extravasation of urine (Figs. 676, 677) from rupture of the bulbous urethra, which is the most common site of that accident, usually as a result of falling astride a hard, narrow object, or blows or kicks in the perineum. The second most common site of rupture is in the membranous urethra.

TUNICA ALBUGINEA AND ERECTILE TISSUE. Each erectile body is surrounded by a distensible, elastic, resistant, fibrous envelope, the TUNICA ALBUGINEA, the trabeculae of which surround blood spaces or areolae (Fig. 675). Where the corpora of the penis are applied against one another, the albuginea forms a median septum or partition, the *septum* of the *penis*. The areolae or blood spaces, which form the hypertrophied vascular layer of the urethral mucosa, are dilated and more highly developed in the corpora of the penis than in the corpus of the urethra. The number of areolae explains why injuries to the penis are accompanied by abundant hemorrhage, and why such hemorrhage is stopped easily by compression. In certain cases of gonorrhea the blood spaces in the cavernous body of the urethra are involved, and, as a result, elasticity and dilatability may be lost to the extent that there is a downward curved erection of the penis and acute pain, a condition known as *chordee*. Wounds involving the erectile tissue, if transverse and extensive, are followed by scar tissue formation and loss of erectile power over the region distal to the injury. Fracture may occur when the bodies have undergone calcification or are subjected to violence while they are in a state of erection.

VESSELS AND NERVES. The vessels and nerves to the erectile organs are the deep and main supply to the penis (Fig. 678). The *arteries* supplying the erectile tissue are the terminal branches of the internal pudendal, the paired bulbourethral, dorsal and cavernous arteries. The dorsal arteries to the penis lie on the

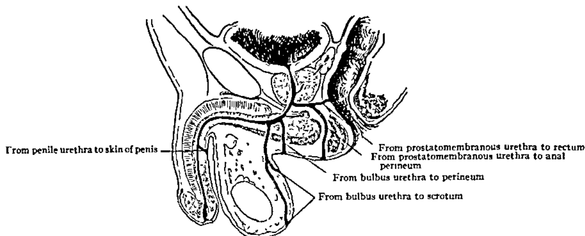


Fig. 681. SAGITTAL SECTION THROUGH THE MALE PELVIS AND EXTERNAL GENITALS TO SHOW URETHRAL FISTULAE.

Adhesions between the deep surface of the prepuce and superficial surface of the glans may prove partly causative. The narrow preputial orifice hinders urinary outflow and causes straining. The redundant prepuce sometimes forms a sort of reservoir into which part of the voided urine settles, to be discharged subsequently through the narrow aperture. Decomposing urine is likely to set up infection of the apposed surfaces of the glans (*balanitis*) and the prepuce (*posthitis*), which may be succeeded by a retrograde urethritis and cystitis.

Circumcision is indicated whenever there is an obvious phimosis (Fig. 682). Adhesions of the prepuce to the glans must be freed, and the

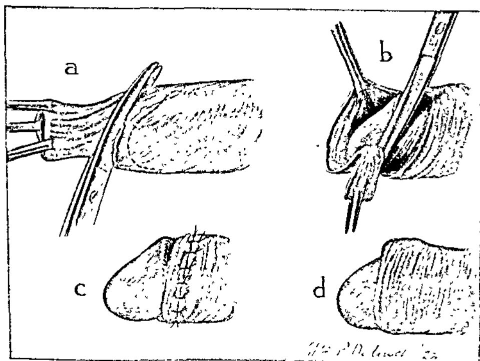


Fig. 682. CIRCUMCISION.

a, The prepuce is drawn down and the redundant skin is excised. A long clamp usually is applied proximal to the line of excision to avoid injury to the glans; *b*, the redundant inner (mucous membrane) layer of prepuce is excised; *c*, the closure is by interrupted sutures; *d*, the partial covering of the glans when the proper amount of prepuce is removed. (From Young: Practice of Urology.)

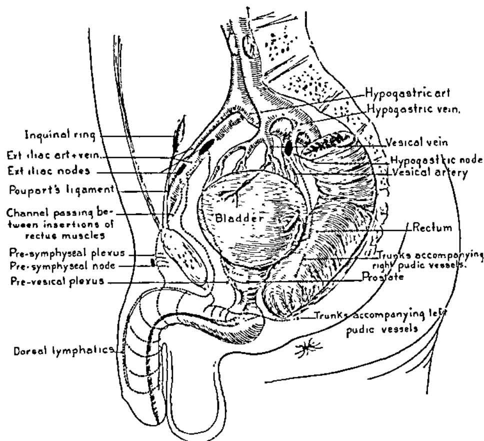


Fig. 679. DIAGRAM SHOWING THE COURSE TAKEN BY THE LYMPHATIC CHANNELS DRAINING THE URETHRA.

Lymphatics from the penile portion form part of the dorsal lymphatics. They do not enter the subinguinal nodes. Some drain to a small channel passing between the insertions of the right and left rectus muscles to enter the external iliac node. There are anastomoses beneath the symphysis with the lymphatics of the bulbar and membranous portions of the urethra. The bulbar lymphatics drain mainly into trunks accompanying the internal pudendal vessels to enter the hypogastric nodes. At the apex of the prostate there are anastomoses with the prevesical lymphatic plexus, with the prostatic plexus, and doubtless with the lymphatics of the ejaculatory ducts and vasa deferentia. (From Young: Practice of Urology.)

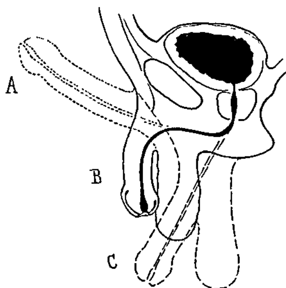


Fig. 680. URETHRAL CURVES IN SAGITTAL SECTION. *A*, During erection; *B*, in repose; *C*, penis drawn down to admit straight instrument.

membranous portion. Once this level is reached, little difficulty is encountered in entering the bladder, save in certain cases of enlarged prostate when the corresponding segment of the urethra becomes elongated and acquires a much accentuated anteroposterior curve.

Fistulae of the urethrae may perforate the cavernous tissue of the penile body to reach the free surface of the skin or may open into the rectum. Other routes followed by fistulous tracts are the following: ischiorectal fossa to the anal perineum; superficial compartment to the urogenital part of the perineum; scrotum, from the bulb of the urethra (Fig. 681).

Surgical Considerations

PHIMOSIS AND CIRCUMCISION. When an excessively long narrow prepuce, because of its constriction, cannot be drawn back over the glans, the condition is known as *phimosis*.

edge of the preputial ring exerts an unusual amount of constriction, circulation is seriously interfered with, and ulceration, or even gangrene, of the foreskin and head of the penis may occur. Were it not for the rich blood supply of the glans, this complication would be much more frequent.

Treatment consists in replacing the prepuce by exercising heavy pressure on the glans with the thumbs, while maintaining traction on the prepuce with the encircling fingers. In advanced stages the constricting preputial ring must be incised (Fig. 683).

Amputation of the Penis. Carcinoma of the penis is the usual condition for which amputation of the organ is required. Removal may be partial or complete, depending upon the size of the lesion, its duration, and degree of malignancy. For *partial amputation* a skin flap may be fashioned from the ventral aspect of the organ and folded over the end of the stump to provide a satisfactory covering. Particular attention should be paid to the removal of Buck's fascia from the stump as far back as the suspensory ligament (Young). Intensive treatment requires a lymphatic resection on both sides of the superficial inguinal, deep femoral and iliac lymph nodes (Figs. 621, 685). For a recurrent or extensive lesion it is imperative to perform a *complete amputation*. This operation should always be combined with the radical lymph node dissection already outlined.

Scrotum and Spermatic Cord

Scrotum. The scrotum is like a bag, within which are lodged the testes and the lower portions of the spermatic cords. Originally it consists of two folds, one on each side of the urogenital furrow. Later these fuse, and a vestige of the fusion remains as the median raphe, continued into the perineal skin behind the scrotum and along the lower aspect of the penis, anteriorly. Its homologue in the female remains permanently separated as the labia majora.

The *scrotal skin* is of delicate texture, usually darker than that in the adjoining regions, and is semitransparent and distensible (Fig. 684). Contraction of the subjacent dartos causes it to present a wrinkled or corrugated appearance. The *dartos* tunic is a smooth, thin layer of *involuntary muscle lying immediately beneath* the skin and intimately adhering to it (skin-dartos layer). It is prolonged backward into the superficial perineal fascia (of Colles) (p. 689). This platysma-like muscle contracts with cold and relaxes with heat; its tonicity decreases with age. At the median raphe the dartos gives off a sagittally disposed septum dividing the scrotum into right and left pouches, each of which forms a distinct sac containing the corresponding testicle and its coverings. This

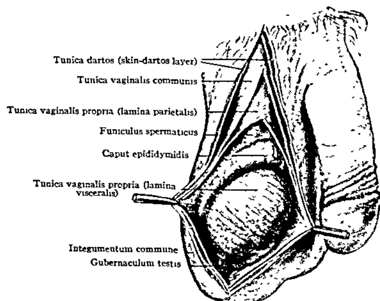


Fig. 684. RIGHT TESTICLE AND TERMINAL PORTION OF THE SPERMATIC CORD WITH THEIR COVERINGS.

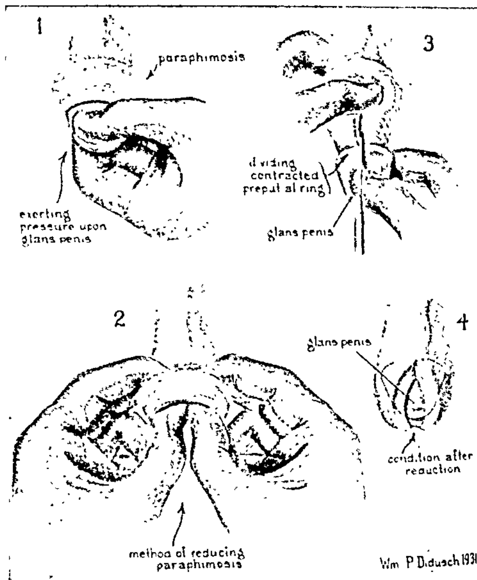


Fig. 683. OPERATION FOR PARAPHIMOSIS.

1 and 2, Reduction of paraphimosis. 3 and 4, Dorsal slit necessary when paraphimosis cannot be reduced by manipulatio and done in some cases of phimosis. (From Lowsley and Kirwin: Clinical Urology. Baltimore, Williams & Wilkins Com pany.)

prepuce must be pulled back over the corona of the glans before circumcision is begun. When the prepuce is cut away, the outer skin of the cuff retracts, but the deep layer remains in contact with the glans. The deep layer of the prepuce is trimmed off the glans to a point half the distance back to the coronary sulcus, special care being taken to preserve the frenum. The tributaries of the dorsal vein and arteries require ligation, as may the small artery of the frenum. The cut edge of the skin is sutured to the deep layer of the prepuce.

In some cases in which phimosis has been induced by cicatricial contracture, a *dorsal slit* (Fig. 683) or complete circumcision will be necessary.

PARAPHIMOSIS. Paraphimosis results whe the prepuce, having been drawn back to un cover the glans, cannot be drawn forwar again, but forms a constricting band behin the corona. The glans may become edematou and engorged, but the prepuce, because of it laxity of structure and the obstruction to th return of its venous flow, swells to such degree as to form an edematous collar sur rounding the neck of the penis. Behind thi constricting band there often is a deep ex coriated sulcus and a second edematous ban less marked than the first. The penis seems t take an upward bend at the neck, the appear ance being caused mainly by the large amoun of swelling about the frenum. When the tens

small vessels which must be ligated carefully to prevent postoperative scrotal hemorrhage. The *scrotal lymphatics* form an exceedingly rich network, the main stems of which drain to the medial group of subinguinal glands (Fig. 685).

The *cremaster muscle* (Fig. 369, p. 378), with its looplike fibers, forms a partial investment for the testis and cord. As these thin muscle strands reach the gland, they thin out and are fused to the parietal layer of the tunica vaginalis, in company with a fibrous layer derived from the internal spermatic (infundibuliform) fascia. By the contractions of this musculofibrous layer the testis is drawn toward the subcutaneous inguinal ring. Scratching the skin of the medial aspect of the thigh produces a strong cremasteric contraction, the *cremasteric reflex*.

TUNICA VAGINALIS TESTIS. The tunica vaginalis propria, derived from the vaginal process of the peritoneum (Fig. 684), lines the inner aspect of the scrotum and sheaths most of the testis and epididymis. The remainder of the funicular or upper portion of the process (vaginal ligament) extends from the internal ring to the epididymis and lies among the elements of the spermatic cord (Fig. 369).

As is true of all serous cavities, the tunica vaginalis has a visceral and a parietal leaf with a potential cavity between them. The *visceral layer* is closely adherent to the fibrous covering of the testis and epididymis (tunica albuginea), and dips in between the upper part of the testis and epididymis to form a pouch, the digital fossa or sinus of the epididymis. The visceral serosa extends for a short distance upward along the cord, covering it upon each side and in front (Fig. 684). The part of the testis not covered by the visceral layer of the tunica vaginalis corresponds to the posterior border of the hilum of the gland, where its vessels enter and leave and where the excretory duct (vas deferens) passes upward into the cord. The *parietal layer* is separated from the scrotum by a thin layer of extravaginal cellular tissue. It is resistant, but it may be distended by accumulation of fluid in a vaginal hydrocele.

EPIDIDYMIS AND TESTIS (TESTICLE). The term "testicle" in this discussion includes the spermatic gland (testis) and its mass of collecting tubules (epididymis). The testicle (Figs. 684, 686), loosely suspended by the spermatic cord and its investing tunics, is in contact with the posterior wall of the scrotum and is attached to its base by the so-called *scrotal ligament*.

The EPIDIDYMIS is a crescent-shaped body connected with, and surmounting, the posterior border of the testis (Figs. 684, 686). It is composed mainly of an elaborately coiled tube connected at the upper pole of the testis with the ducts (vasa efferentia) emerging from the superior pole of the gland. By its lower extremity the epididymis is continued into the *ductus* (*vas*) *deferens*. The epididymis consists of three parts: an upper expanded portion, the *globus major* or *head*, which surmounts the upper pole of the testis; a smaller, lower extremity, the *globus minor* or *tail;* and an intervening portion, the *body*. Most of the epididymis is invested by the tunica vaginalis. Occasionally it is connected less intimately with the testis than usual, the connection taking the form of a duplication of the tunica vaginalis. In *epididymectomy* an anterior approach should be used and the epididymis be carefully disengaged from the testis to avoid injury to the testicular vessels.

Each lobule of the TESTIS consists of greatly convoluted *seminiferous tubules*, from the epithelial cells of which the spermatozoa are formed. As the tubules approach the mediastinum of the testis, they unite to form a number of ductlike passages which converge at the upper extremity of the gland into the *efferent ductules*. These ductules form the mass of the globus major and open separately into a single canal, the duct of the epididymis, which forms an exceedingly tortuous passage, continued into the vas deferens at the lower extremity of the gland.

The pearly white *tunica albuginea* surrounding the testis and epididymis is a fibrous layer somewhat resembling in appearance the sclerotic layer of the eyeball. From the deep aspect of this covering, numerous fibrous septa pass radially backward to the connective tissue at the hilum of the testis (*mediastinum testis*).

A knowledge of the normal relations between the testis and epididymis is important in conducting the examination of these parts. The normal testis is smooth, firm and elastic. Squeezing it beyond a certain point causes a peculiarly nauseating pain, normal testicle sensation. The different portions of the epididymis may be differentiated readily, particu-

partition limits a scrotal effusion to one or the other space.

The dartos layer is connected to the subjacent testicles and their envelopes by *subdartos connective tissue* (Fig. 684). This tissue is sufficiently loose to permit the testis, epididymis and cord to move about freely beneath the skin and to allow their easy enucleation when the skin-dartos layer is sectioned. Within the potential spaces of this loose tissue, which is freely continuous with the cellular tissue of the perineum, penis and abdominal wall, hematomas and urinary extravasations readily localize. This tissue is traversed by numerous

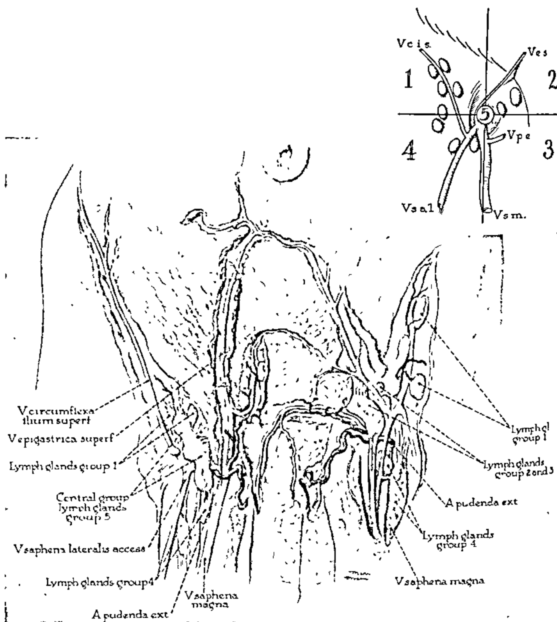


Fig. 685. SUPERFICIAL VEINS AND LYMPH NODES OF THE ANTERIOR FEMORAL AND ADJACENT INGUINAL AND PUDENDAL REGIONS.

The superficial fatty stratum is here left intact except where it contains lymphatic glands and blood vessels. The vessels have not been transected, but are exposed *in situ* by removing the immediately surrounding adipose tissue. In this way the extent of the lower abdominal, proximal femoral and pudendal areas of vascular and lymphatic drainage is depicted, and the fascial level of the glands and vessels recorded.

In the inset are shown, diagrammatically, the saphenous vein and tributaries in relation to the inguinal glands of most frequent occurrence. The glands are separable into 5 groups; 4 of the groups are bounded by lines which meet at the saphenofemoral junction; the fifth group would lie upon the vessels at the latter junction. Abbreviations: *V.c.i.s.*, vena circumflexa iliaca superficialis; *V.e.s.*, vena epigastrica superficialis; *V.p.e.*, vena pudenda externa; *V.s.a l.*, vena saphena accessoria lateralis; *V.s.m.*, vena saphena magna.

various directions in the pelvic extraperitoneal space. The size of the cord occasionally is increased by a hydrocele (p. 382), an encapsulated mass of fat (lipoma) or a group of varicose veins (varicocele).

The *deferent duct* (*vas*) begins in the tail of the epididymis, of which it is the prolongation and with the pathologic changes of which it is allied. A thickened vas deferens with tuberculous epididymitis indicates upward extension of the disease. The firm consistency of the muscular wall of the vas is recognized readily among the other elements of the cord. Normally the vas is bluish-white, resembling cartilage, smooth and supple; when inflamed by tuberculosis, it is elongated and presents a rosary-like appearance. It is related anteriorly to the anterior or spermatic group of veins surrounding the testicular artery and to the remains of the vaginal process of peritoneum. Because of the latter relationship, the sac of a congenital inguinal hernia usually is found anterior to the vas. Posteriorly, the vas is related to the deferent group of veins.

Blood Vessels and Lymphatics. The *arteries* of the cord are the testicular (internal spermatic) artery of the vas and external spermatic artery from the inferior epigastric (Fig. 686). The testicular artery branches from the abdominal aorta in the lumbo-iliac region and engages the cord at the abdominal inguinal ring. Within the cord it is so surrounded by the anterior or spermatic group of veins as to be masked in the course of operation. The artery of the vas deferens is a branch of the superior vesical artery and accompanies the duct to its origin, being everywhere adherent to it and loosely incorporated within its sheath. Because of the free anastomosis between the testicular artery and the artery of the vas, division of the former is devoid of serious consequences if the integrity of the artery to the vas is preserved.

The *veins* of the cord arise in the testis and epididymis and are remarkable for their number, size, and tendency to become varicose (Fig. 686). Those emerging from the testis are joined by others from the globus major, and all ascend within the cord in a plexiform manner (pampiniform plexus). They are alluded to surgically as an anterior or spermatic group about the testicular artery, and a posterior or deferent group intimately associated with the deferent duct. The anterior group is more prone to become varicose.

The lymphatics of the testis, epididymis, vas deferens and tunica vaginalis have no connection with the inguinal lymph nodes, but retain the channels associated with their embryologic development. The testes, originating just below the kidney, have efferent lymphatic channels that drain to lymph nodes in relation to the aorta, inferior vena cava and renal pedicle (Fig. 687). On the other hand, the epididymis, vas deferens and tunica vaginalis lymphatics drain to lymph nodes in the region of the external iliac artery. This knowledge is essential to the intelligent treatment of testicular tumors.

In addition to the elements just enumerated, the external spermatic (cremasteric) artery and genital (external spermatic) branch of the genitofemoral nerve accompany the structures of the spermatic cord.

Surgical Considerations

Thoracoabdominal Approach for Radical Retroperitoneal Lymph Node Dissection for Testis Tumors. Following the satisfactory use of the thoracoabdominal approach for the removal of large renal tumors, this incision has been found to permit a relatively easy dissection of retroperitoneal nodes for carcinoma (Fig. 688).

Anomalies in Position of the Testicle. Abnormalities in position of the testicle usually are congenital and result from some defect in the descent of the testis into the scrotum.

In *inversion* the testicle reaches the scrotum, but occupies a variety of twisted or inverted positions within it, designated according to the position of the epididymis. In the superior type of inversion the epididymis surmounts the testicle and runs horizontally forward. The inversion is anterior if the epididymis is anterosuperior rather than posterosuperior, the testicle having rotated forward 180 degrees through its transverse axis.

Torsion of the entire testicular mass may occur within the scrotum, so that the cord is twisted in its extravaginal portion. To allow twisting to occur, the loose areolar connections between the outer surface of the tunica vaginalis and the skin-dartos layer of the scrotum must be broken. A *lateral* torsion is lateral or medial accordingly as the epididymis lies on its lateral or medial aspect. When the tunica vaginalis furnishes an abnormally long mesentery-like duplication to the testis and epididy-

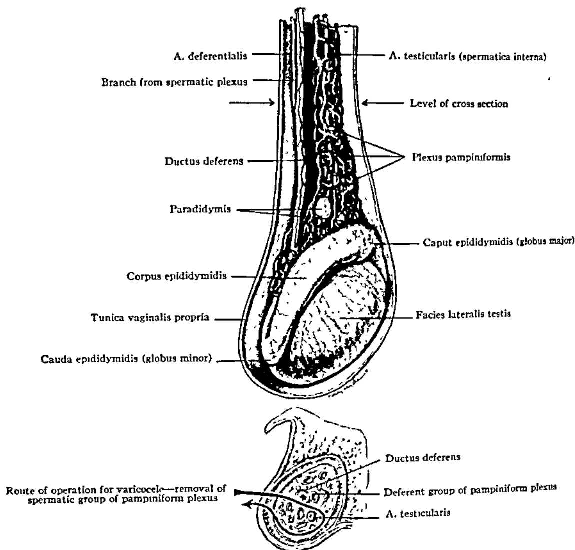


Fig. 686. LATERAL VIEW AND CROSS SECTION OF THE RIGHT SPERMATIC CORD AND TESTICLE. Cross section illustrates the removal of the spermatic group of veins of the pampiniform plexus for varicocele.

larly the globus major. Inflammatory enlargement of the testis and epididymis is produced by tuberculosis, gonorrhea and syphilis.

Epididymitis is commonly of tuberculous, gonorrheal or pyogenic origin. Theoretically, if the globus minor is involved first, a descending infection is responsible, either gonococcal or nonspecific pyogenic. If the globus major is involved first, tuberculosis is responsible. Whether the primary focus of genital tuberculosis is in the seminal vesicles or in the testis is debatable, since infection may travel directly or by the blood stream and lymphatics. When the inflammatory process involves bilaterally the duct of the epididymis or the beginning of the vas deferens, sterility is the inevitable consequence. Because of the intimate connection between the epididymis and testis, reciprocal infection is common (epididymo-orchitis). A gradual enlargement of the testis, accompanied by diminished testicle sensation, suggests syphilis; rapid enlargement of the testis, in the absence of an inflammatory lesion or injury, suggests malignancy.

Spermatic Cord. The spermatic cord begins at the posterosuperior margin of the testicle, to which organ it supplies a supporting pedicle within the scrotum, and ends at the abdominal inguinal ring. The structures comprising the cord are the deferent duct and the vessels and nerves of the testicle (Fig. 686). These structures are united by loose cellular tissue within a common sheath (p. 378). The *scrotal course* of the spermatic cord ascends almost vertically to the front of the pubic crest, where it can be palpated readily through the scrotal tissues. After running an *inguinal course* to the deep inguinal ring, the constituent elements run in

mis, torsion may be intravaginal. Twisting effectively occludes the veins, but not the arteries, to the gland, so that the tissue distal to the twist becomes a hemorrhagic infarct.

In *irregularities in the descent of the testicle* (*retained or undescended testicle*) the gland may not reach the scrotum, but be retained somewhere in its normal course of descent between the abdominal position and the scrotum. Strictly speaking, the term *cryptorchidism* applies to those cases in which one or both of the testes are hidden from view, but has come to include all varieties of retention. The testicle may lie in contact with the posterior abdominal wall (abdominal or supravaginal retention), in the iliac fossa (iliac retention) or at some point between the subcutaneous inguinal ring and the upper part of the scrotum. An incompletely descended testicle often is associated with a patent vaginal process (peritoneovaginal canal) and a congenital inguinal hernia.

Not only may the testicle fail to reach the scrotum and be retained at some point along the line of normal descent, but also it may migrate to an aberrant or *ectopic position* outside the normal course. It may miss the inguinal canal and emerge by way of the femoral opening to an anterior position on the thigh (femoral ectopia). More frequently the testicle, after traversing the inguinal canal, descends beyond its normal position and comes to lie in the perineum, anterior to the anus (perineal ectopia). The testicle has been found in the true pelvis (intrapelvic ectopia) beneath the bladder.

VARICOCELE AND ITS OPERATIVE TREATMENT. In varicocele there is dilation, elongation and tortuosity of the veins of the spermatic cord (pampiniform plexus). It is much more common on the left than on the right side, and is accentuated just above the testis. In some instances the normal veins are increased greatly in size with no appreciable increase in number, while in others the number of veins is increased markedly. When the patient stands, the veins form curious loops and coils within the cord which suggest to the touch a "bag of worms." The bulk of the mass of veins belongs to the anterior group surrounding the testicular artery. When the patient lies down, the veins empty themselves, and the varicocele disappears.

Among the many explanations of the cause of varicosity in the spermatic veins are lack of external support, great length and tortuosity of the veins, and imperfect development of the valves. The union of the left spermatic vein with the left renal vein at a right angle, together with the fact that it is overlaid by the sigmoid colon, the weight of which, in cases of



Fig. 688. THORACOABDOMINAL INCISION FOR RETROPERITONEAL LYMPH NODE DISSECTION.

This route has been used for the radical removal of retroperitoneal lymph nodes associated with tumors of the testis (Fig. 687), and large renal tumors. The incision is made over the tenth rib from the posterior axillary line to the costochondral junction, and extended obliquely down into the lower quadrant of the abdomen to a point midway between the internal inguinal ring and the lateral border of the rectus muscle. The tenth rib is resected, and the pleural and retroperitoneal spaces opened. The diaphragm is divided for a distance of 10 to 12 cm. dorsolaterally, providing ready access of the retroperitoneal space after mobilization of peritoneum and Gerota's fascia from the under surface of the diaphragm. The retroperitoneal gland dissection is carried out *en bloc* within Gerota's fascia anterior and posterior to the renal pedicles, from the level of the crus of the diaphragm to the internal inguinal ring, including all the lymph nodes in relation to the great vessels. It is evident that, when extension of retroaortic or retrocaval glands is found, inoperability must be considered. However, careful retraction and dissection will allow the surgeon to resect a majority of these nodes. Ligation of large lymph channels, when encountered, is necessary to obviate lymph fistulae. Closure of the incision is made in an anatomic fashion. (From Cooper, Leadbetter and Chute: Surg., Gynec. & Obst., 90: 486–96, 1950.)

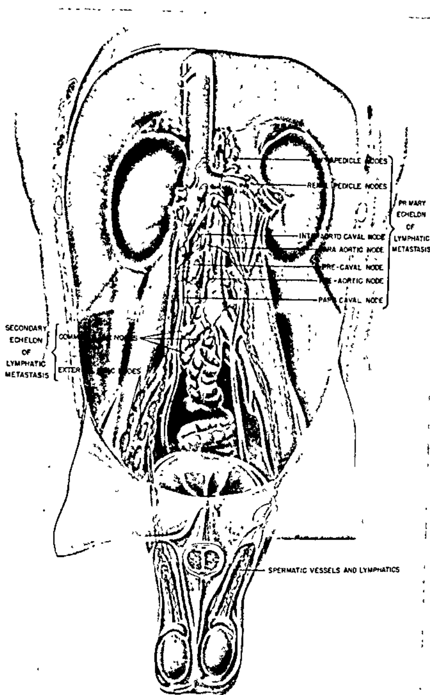


Fig. 687. LYMPHATIC DRAINAGE FROM THE TESTIS, IN RELATION TO METASTASIS FROM TESTIS TUMORS

The lymphatics of the testis and epididymis have no connection with the inguinal lymph nodes, but drain to areas of their embryologic development. As shown on the right side, the efferent lymphatic channels arising in each testis pass in conjunction with the spermatic vessels through the inguinal canal into the retroperitoneal space. At the point where the spermatic vessels cross the ureter, the channels veer medially to be distributed to lymph nodes in relation to the aorta, vena cava and renal pedicle. The left side demonstrates that, when the primary area of nodes is blocked by metastases, many collateral and retrograde lymphatics are involved, resulting in spread to secondary sites in the opposite lumbar chain and to the iliac system. Anatomically, direct metastasis to iliac glands can occur only when the primary tumor invades the adjacent epididymis, since the normal lymphatic drainage of this organ is to glands situated in relation to the external iliac artery and vein. (From Cooper, Leadbetter and Chute: Surg., Gynec. & Obst., 90: 486–96, 1950.)

constipation, may impede the venous return, is judged to impede venous flow. These theories do not explain the occurrence of varicocele in the young and its comparative absence in the old, in whom conditions supposedly are ideal for its development.

In most cases of varicocele, surgical treatment is not indicated. A high degree of neurasthenia is associated with the condition, and most varicoceles spontaneously disappear with the passage of time. Only when the veins are decidedly enlarged should operation be done.

The most commonly performed operation is that of ligation and excision of the involved veins in the scrotum, using a vertical incision through the skin-dartos layer in a low inguinal or high scrotal position (Fig. 689). A more recent conception of the treatment involves ligation of the spermatic veins at the internal inguinal ring in order to eliminate the static column of blood responsible for the varicocele, yet not to disturb the arterial circulation to the testis or impair the collateral venous circulation either in the cord or at the external ring (Fig. 690).

HYDROCELE. A hydrocele is a circumscribed collection of fluid usually occupying the cavity

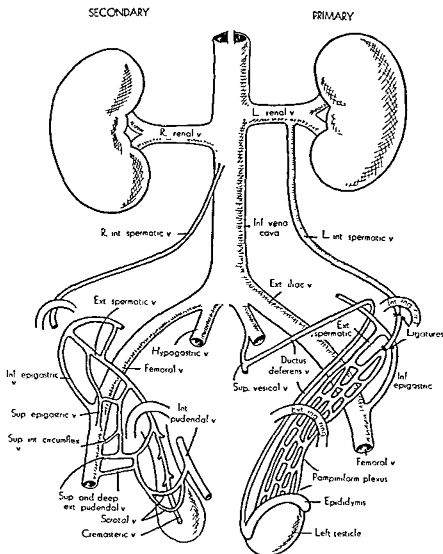


Fig. 690. LIGATION OF THE INTERNAL SPERMATIC VEIN FOR VARICOCELE.

Ligation of the internal spermatic vein at the internal inguinal ring does not interfere with the collateral circulation between the primary or deep (originating in the pampiniform plexus—shown on the right) and *the secondary or superficial* systems (shown on the left) of veins. It eliminates the static column of blood producing the varicocele. With care the internal spermatic artery is separated from the vein, or veins, when the latter is ligated. (From Javert and Clark: Surg., Gynec. & Obst., 79: 644-50, 1944.)

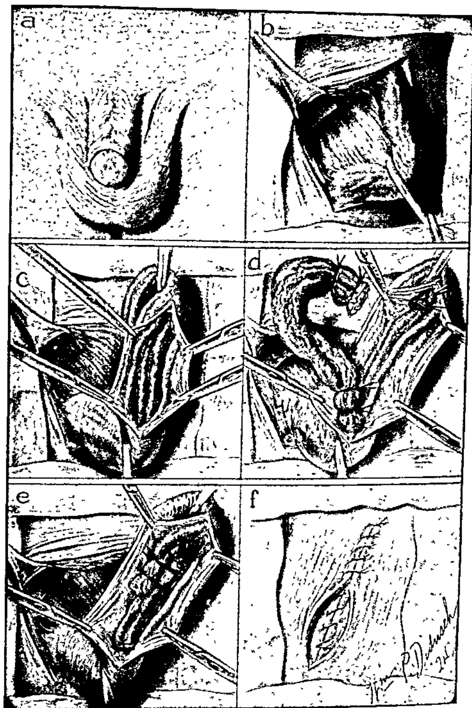


Fig. 689. OPERATION FOR VARICOCELE.

a, High scrotal incision; *b*, cord freed and drawn out; *c*, covering of the cord opened, exposing veins and vas; *d*, resection and removal of redundant veins; double ligature of stump with catgut; veins, vas and artery of vas preserved; *e*, ends of veins bound together to elevate and support testis; *f*, closure of skin-dartos layer and sheath of cord. (From Young: Practice of Urology.)

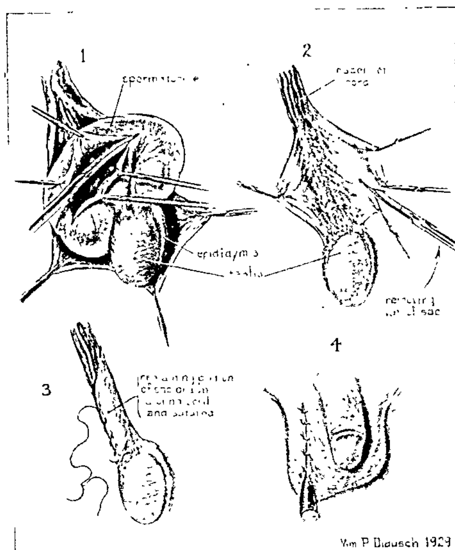


Fig. 692. EXCISION OF SPERMATOCELE.

The scrotum and tunica vaginalis have been incised, exposing the testis and spermatocele. 1, Spermatocele incised. 2 and 3, The cyst wall resected except for a small portion which is sutured about the cord. 4, Wound closed, with drainage to prevent a hematocele. (From Lowsley and Kirwin: Clinical Urology. Baltimore, Williams & Wilkins Company.)

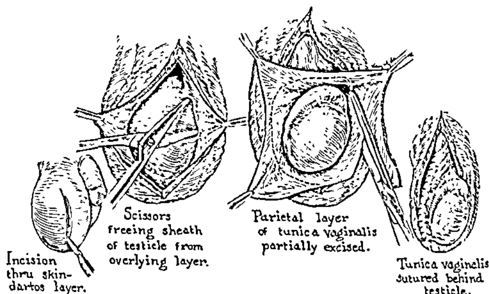


Fig. 691. OPERATION FOR HYDROCELE OF TUNICA VAGINALIS.

of the tunica vaginalis (vaginal hydrocele), but sometimes occurring in the spermatic cord. In the more common PRIMARY FORM, *vaginal hydrocele* (Fig. 691), the fluid collects slowly, unaccompanied by pain or evident distress. This hydrocele occasionally attains an enormous size, greatly distending the scrotum. A type frequently seen is that associated with incomplete obliteration of the funicular part of the vaginal process above the tunica vaginalis (*funiculovaginal hydrocele*). This variety may extend superiorly to any level in the spermatic cord and reach even the internal abdominal ring. This condition closely resembles an inguinal hernia. The contents of a hydrocele can be returned to the abdominal cavity only if it is of the congenital or infantile type.

Differentiating a hydrocele from a scrotal hernia is usually not difficult. A hydrocele does not enter the abdomen, so that the fingers can reach above the mass in the scrotum. Transillumination with a bright light is possible with most hydroceles, and the testicle occupies a posterior position. A hernia is not translucent, it gives an impulse on coughing, and the testicle lies in the bottom of the scrotum.

The acute or secondary form of vaginal hydrocele is associated with inflammation of the testis and epididymis.

Treatment of a hydrocele may be by three ways: (1) by tapping, (2) by tapping followed by injection, (3) by open operation (Fig. 691).

SPERMATOCELE. These are retention cysts within the scrotum which contain spermatozoa, and arise from the vas efferens, vas deferens or appendix testis (p. 719). They are usually painless and may reach a large size. They appear as a globular mass above the testicle in the extravaginal form, and as a piriform mass displacing the testicle downward and forward if intravaginal.

Small spermatoceles require no treatment. Larger tumors may be tapped and injected with an irritant solution, as for hydrocele, or surgically excised (Fig. 692).

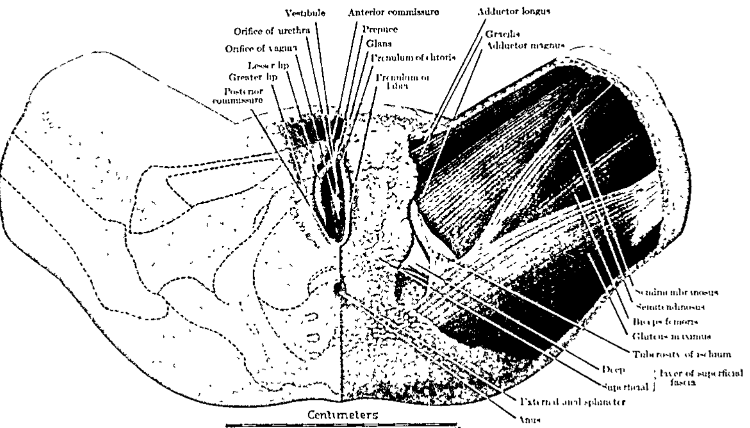


Fig. 693. FEMALE PERINEUM, AT THE LEVELS OF THE INTEGUMENT AND THE SUPERFICIAL FASCIA.

On the subject's right the external genital organs are shown; on the left the layers of the superficial fascia are demonstrated in their relationship to the uregenital and anal portions of the perineum.

In the following figures the perineal structures are followed to successively deeper levels.

CHAPTER 23

Female Perineum

The perineum is the anatomical region at the inferior end of the trunk between the thighs. Externally it is a deep cleft when the thighs are approximated, but when the latter are abducted, it becomes a broad, lozenge-shaped area (Fig. 693). Deeply (Fig. 698) it is limited in front by the pubic symphysis and the arcuate ligament, on each side by the inferior rami of the pubis and the ischium, the ischial tuberosity and the sacrotuberous ligament, and behind by the sacrum and the tip of the coccyx. On the surface (Fig. 693) it is bounded in front by the mons veneris, which rests upon the pubis, behind by the gluteal region (buttock), and at the sides by the femoral region (thigh). In occupying the interval enclosed by the hip bones and the sacrum, it contains all the structures situated within the pelvic outlet. Upon its surface terminate the urogenital tract and the alimentary tract, respectively in front of and behind an arbitrary transverse line joining the ischial tuberosities. The perineum as a whole may then be conveniently divided into an anterior urogenital triangle or region, and a posterior anal triangle.

Anal Division of the Perineum

External Anatomy and Anal Canal. The anal canal opens to the exterior in the middle of the anal triangle (Fig. 693). The skin surrounding it is pigmented and thrown into folds, and contains the large, circumanal sweat glands. The anus is situated about 2.5 cm. in front of the tip of the coccyx, and forms the truncated end of the funnel-shaped muscular and fascial support, the pelvic diaphragm. To either side of the anal canal, and the diaphragm upon which it terminates, lies a space termed the ischiorectal fossa (Fig. 694). The superficial fascia over this posterior part of the perineum is remarkable for the considerable amount of fat in its meshes; in the form of two adipose pads it fills the spaces of the fossae, extending deeply between the ischium and the rectum, on each side of the median line.

Ischiorectal Fossae. Each fossa and the contained mass of fatty connective tissue is prismatic in shape. The fossae are widest and deepest behind, narrowest and shallowest in front, being here encroached upon by the ascending pubic arch. The lateral vertical wall (Figs. 696, 698) is formed by the ischium, covered by the parietal fascia investing the obturator internus muscle; the medial wall is formed by the diaphragmatic fascial layer, which covers the under surface of the levator ani and coccygeus muscles. The apex of the fossa is situated at the line of junction of these fasciae, since anteriorly the fossa does not end at the base of the urogenital diaphragm, but continues forward, between the latter and the pelvic diaphragm, into the urogenital part of the perineum. Posteriorly the basal aspect of the space is limited by the sacrotuberous ligament and the gluteus maximum muscle, above the lower border of which it extends into a posterior recess (Fig. 696).

On the lateral wall of the fossa, and above the lower margin of the ischial tuberosity, the fascia of the obturator internus muscle is elevated to form a canal (Alcock's) for the internal pudendal vessels and the pudendal nerve, which are coursing toward the urogenital part of the perineum (Fig. 700). Originating from them, near the tuberosity of the ischium, the inferior hemorrhoidal vessels and nerves pierce the fascial canal, passing medialward and forward through the fatty connective tissue pad of the fossa to the anal canal (Fig. 694); nerves and veins accompany the arteries.

External Anal Sphincter. The outer sphincter muscle is a subcutaneous group of skeletal (striated) muscle fibers which surrounds the margin of the anal canal (Fig. 694).

The inner fibers, which form a strong ring, are separated from the nonstriated fibers of the internal sphincter, the intrinsic cylindrical muscle of the canal, by the levator ani muscle of the pelvic diaphragm. The external sphincter forms an elliptical structure which measures 5 cm. in length and 4 cm. in extreme width; from the rounded ends of the oval collar pass fibers which are attached to the terminal portion of the coccyx behind, and blend with the superficial perineal muscles at the central tendinous point of the perineum in front (Fig. 694).

ANOCOCCYGEAL BODY. The posterior part of the external sphincter becomes enmeshed in a rather indefinite body of fibrous and muscular tissue which lies between the levator ani muscle and the coccyx; situated in this position, it serves as a support for the lower part of the rectum and the anal canal. To its mass the external sphincter and the levator ani contribute the muscle fibers. The soft, adipose, fibrous tissue in the two ischiorectal fossae—of which tissue the anococcygeal body may be considered a modified nodular portion—is continuous with the general fatty pannicle of the gluteal and of the femoral regions (Fig. 693). As the layer is continued outward toward the medial side of the thighs and over the tuberosities of the ischia, it undergoes further modification: the fibrous content becomes tough and stringy, dividing the contained fat into separate lobules, and fastening the skin to the subjacent bone and deep fascia.

Urogenital Division of the Perineum

EXTERNAL GENITALS. The urogenital part of the perineum contains the urethral opening and the external organs of generation. To the latter group of structures is applied the collective term "pudendum" (vulva); it comprises the greater lips and the genital parts which lie between them, namely, the lesser lips, the body and glans of the clitoris, and the vaginal orifice. The pudendum forms a keel-shaped eminence (Fig 693), wider in front than behind, extending from the pubis to a point in front of the anus, and enclosing a deep median cleft.

Greater Lips and Commissures. Each greater lip (labium majus) is homologous to a half of the scrotum in the male, and the line of the vestibular or pudendal cleft between the two lips corresponds in position to the scrotal raphe. Since the labia majora are in contact with each other, they are usually the only visible parts of the external genitalia. The labia majora are round folds of integument, the size and shape of which depend upon the amount of underlying fatty tissue. They usually measure about 8 cm. in length and 3 cm. in width. They come together over the pubic symphysis to form a prominent, median, cushion-like elevation, the anterior commissure (mons veneris or mons pubis), and, narrowing as they go posteriorly, are connected again to form a much less distinct posterior commissure (Fig. 693). They are limited lateralward by furrows in the skin, and medially they form the boundaries of the vestibule. Their outer convex surface is covered by ordinary skin, hairclad, and provided with numerous sebaceous glands; the inner surface, which lies against that of the opposite labium, possesses a more delicate skin, with large sebaceous follicles. The subcutaneous tissue is rich in fat, and contains smooth muscle fibers homologous to the more abundant dartos tunic of the male.

Lesser Lips. Each lesser lip (nympha) is a cutaneous fold lying medial to the labium majus. Together the labia minora enclose the vestibule (Fig. 693). In the young they are commonly concealed within the fissure between the approximated labia majora; in the aged and in multiparae they are not infrequently pendulous and visible externally. These paired folds are parallel with and internal to the labia majora, but shorter and much thinner than the latter; they attain their maximum height near their anterior ends. They converge anteriorly as they reach the clitoris, and each terminates by splitting into two even thinner folds; the medial divisions join the sides of the clitoridal glans to form the frenum (*frenulum clitoridis*); the lateral divisions arch hooklike over the glans, and constitute the female prepuce (*praeputium clitoridis*). The labia minora diminish in size posteriorly, where they blend with labia majora. Here, a short distance in front of the posterior commissure, they are connected by a transverse fold of skin (*frenulum labiorum pudendi* or *fourchette*); immediately anterior to and above this fold, between it and the posterior limit of the vaginal orifice, lies a shallow depression or fossa (*fossa navicularis*), dorsally placed in the

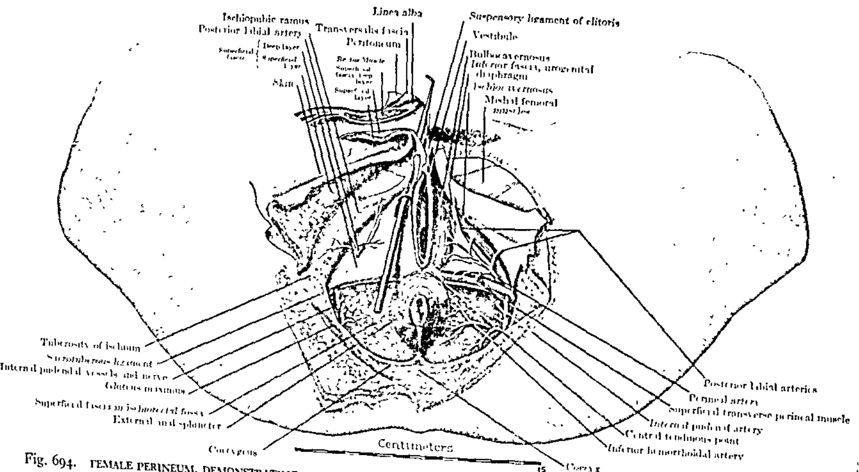


Fig. 694. FEMALE PERINEUM, DEMONSTRATING, ANTERIORLY, THE BOUNDARIES AND CONTENTS OF *THE SUPERFICIAL COMPARTMENT* AND, POSTERIORLY, THE CONTENTS OF THE ISCHIORECTAL FOSSAE.

On the right half of the urogenital triangle the *superficial fatty* layer has been turned aside as a layer to display the deep layer of the superficial fascia. A probe has been passed through an opening in the latter layer and passed forward and upward to the "space" on the inguinal wall situated between *the deep (membranous)* layer of superficial fascia and the outer investing *(innominate) fascia* of the external oblique aponeurosis. The deep layer of superficial fascia, on the left half, has been reflected to reveal the contents of the superficial perineal compartment.

ficial layer leaves the perineum to become continuous with the outer fatty layer on the thighs.

The deep layer of the superficial perineal fascia (Colles' fascia) is wholly different. It is a thin but strong aponeurotic layer, which, except for its continuity in front with the deep layer of the superficial abdominal fascia (Scarpa's fascia), is limited to the anterior half of the perineum, ending behind at a transverse line joining the ischial tuberosities. At the sides of the anterior triangle this dense membranous stratum ends sharply by becoming firmly attached to the ischiopubic rami and the ischial tuberosities (Figs. 694, 695). In the middle line it is divided by the cleft of the vestibule; behind, it marks the line of division between the anal and urogenital portions of the perineum; here it curves upward around the superficial transverse perineal muscle to join the fascia of the urogenital diaphragm (Figs. 618, 694).

Superficial Perineal Compartment. The deep layer of the superficial perineal fascia, in attaching itself to the margins of the bones at the pelvic outlet, forms the floor of a definite pouch in the anterior or urogenital part of the perineum (open in the specimen's left half of Fig. 694); and in becoming continuous posteriorly with the urogenital diaphragm, the same fascia forms the hinder boundary of this triangular pouch, which has been conveniently named the superficial perineal compartment (superficial, or anterior, intra-aponeurotic space, or superficial perineal interspace). The roof, or superior boundary, is the inferior fascia of the urogenital diaphragm. Anteriorly the compartment is open in the sense that the contained space is continuous upward, onto the interval situated between the deep layer of the superficial fascia (Scarpa's) and the deep fascia covering the muscles of the anterior abdominal wall (note probe in Fig. 694). It is through this stratum that an exudate, or blood or extravasated urine dissects its way, other routes being closed through the strength of fascial continuities and attachments.

The compartment contains the erectile or cavernous bodies of the clitoris and their investing muscles; in addition, it is traversed by the vessels and nerves (Figs. 694, 695) which supply these structures, and by those which ultimately leave the space to reach the integument and the subcutaneous tissue of the labia. Through the compartment, in vertical direction and in the medial plane, pass the terminal portions of the urinary and the genital tracts, partially subdividing the space into two.

Erectile Tissue. It has already been stated that the only portions of the clitoris visible when the labia are retracted are the small conical end of the glans and the short body, the latter noticeable only as a low, vertical ridge in the integument covering the lower part of the symphysis pubis. The other constituents of the erectile tissue, with their investing musculature, are housed in the superficial perineal compartment and are brought into view only when the deep layer of the superficial perineal fascia is removed (Fig. 695). The erectile bodies are composed of an intricate, plexiform arrangement of vascular channels, confined in definite masses by tough fibrous tunics. When incised, the cut surface displays channels in the form of cavities, and hence the tissue is referred to as cavernous.

Together the cavernous or erectile bodies form the clitoris and are homologous, though in reduced and modified form, to the components of the penis in the male (Figs. 657, *a*; 658, *a*; 695). The constituent parts of the female organ are the paired corpora cavernosa and the paired vestibular bulbs—the latter joined anteriorly to the glans. Each corpus cavernosum clitoridis corresponds to a corpus cavernosum penis in the male, but is much smaller; and, duplicating the condition in the male, the two corpora cavernosa unite in front to form the body of the clitoris, diverging behind as the crura (each a *crus clitoridis*). The vestibular bulb (bulbus vestibuli) of either side corresponds developmentally to a lateral half of the urethral bulb (*bulbus urethralis* of *corpus cavernosum urethrae*) in the male, but with the difference that the halves in the female remain separate and enclose the space of the vestibule.

The laterally placed corpora cavernosa, through their union anteriorly, form the small, unpaired, cylindrical body of the clitoris. The body, which measures 2 to 3 cm. in length, is bent upon itself and tapers somewhat distally, where it is covered by the glans. Although the two cavernous bars are enclosed in a dense fascial coat (*fascia clitoridis*), some degree of separateness between the symmetrical halves is effected by the clitoridal septum. As the body of the clitoris hangs down in front of the pubic symphysis, it is provided with a suspensory

vestibule (Fig. 693). The labia consist of a hair-free integument which resembles mucous membrane, and an underlying vascular connective tissue which is part of the superficial fascia of the perineum.

Clitoris. Only a portion of the small body and the glans of the clitoris are visible when the labia minora are retracted; otherwise they are concealed by the labia and the mons pubis. The clitoris will be further described in connection with the contents of the superficial perineal compartment (p. 733).

Vestibule. The vestibule (vestibulum, pudendal cleft, urogenital space or fissure) represents the urethral groove of the sexually indifferent embryo, the unfused margins of which come to form, in the female, the labia minora flanking the original cleft. The vestibule opens below onto the surface of the perineum between the labia. It is a fissure elongated anteroposteriorly (Fig. 693); when the lips are drawn apart, it assumes a triangular shape. The apex of the vestibule ends at the clitoris, and its basal part, including the space of the fossa navicularis, is bounded by the frenulum of the labia. The urethral orifice opens into its anterior, the vaginal orifice into the posterior, part (Fig. 694); on each side enters the minute duct of the corresponding greater vestibular gland. Just in front of the urethral opening is a smooth, triangular area of mucous membrane, limited by the clitoris anteriorly and the labia laterally.

Orifice of the Urethra. The external orifice (urinary meatus) is a small opening behind the glans of the clitoris and in the middle line of the vestibule (Fig. 693). Although the shape is variable, it ordinarily assumes the form of a short sagittal cleft; when opened, its diameter is about 4 mm. The mucous membrane around the margin is somewhat elevated and puckered; the papillary projection thus outlined is usually prominent enough to be palpable. Just without the urethral orifice are several minute, crypt-like openings, termed the paraurethral ducts. Skene's ducts, of clinical importance because so often foci of gonorrheal infection, are two small, paired glands approximately 1 cm. in length, situated beneath the floor of the urethra, the orifices of the glands presenting bilateral, almost microscopic openings at the urethral meatus; these glands are the rudimentary homologue of the prostate gland in the male. They are similar histologically to the numerous and separate mucous glands of the urethra, save in the manner in which they may group themselves to employ a common duct.

Orifice of the Vagina. The vaginal orifice opens medially into the vestibule, below and behind the urethral orifice (Fig. 693). Its appearance is wholly dependent upon the condition of the hymen.

Numerous small mucous glands, the lesser vestibular glands, open upon the smooth surface of the vestibular mucous membrane between the urethral and vaginal orifices.

Hymen. The hymen is typically a thin, vascular fold of mucous membrane, attached around the circumference of the entrance into the vagina. In young subjects it occasionally occurs as a complete and imperforate septum; sometimes it is entirely wanting. Usually, however, it is present and displays a small aperture near its midportion which varies in size from pinpoint caliber to an orifice crescentic or circular, admitting a finger's tip (*cf.* Fig. 704). When ruptured in coitus, the opening becomes enlarged, and the fold remains only as a notched or even fimbriated annular membrane; the marginal excrescences of the fold (carunculae hymenales, carunculae myrtiformes) become further reduced to nodular projections after labor.

Deeper Anatomy. *Fascia.* The superficial perineal fascia, whose modifications in the anal region have been described, undergoes a further alteration in the urogenital triangle by dividing into two definite layers, a superficial fatty stratum and a deeper membranous one (Fig. 694). It is, therefore, similar in arrangement to the double-layered abdominal fascia with which it is directly continuous. The superficial of the two perineal layers is part of the general fatty pannicle or superficial fascia covering the entire body, and, like it, is of a loose, areolar texture, with a considerable quantity of fat in its meshes. Posteriorly it is continuous with the adipose pad filling the ischiorectal fossa on each side of the anus; anteriorly it shares in the formation of the labia majora and the mons veneris, and is carried upward in front of the pubes (Fig. 694) as the superficial, fatty layer (Camper's fascia) on the lower portion of the anterior abdominal wall. Where it covers the labia, fat becomes somewhat scarcer in its meshes, giving place to a thin layer of involuntary muscular fibers which represent those of the dartos tunic in the scrotum of the male. Lateralward, the super-

ficial layer leaves the perineum to become continuous with the outer fatty layer on the thighs.

The deep layer of the superficial perineal fascia (Colles' fascia) is wholly different. It is a thin but strong aponeurotic layer, which, except for its continuity in front with the deep layer of the superficial abdominal fascia (Scarpa's fascia), is limited to the anterior half of the perineum, ending behind at a transverse line joining the ischial tuberosities. At the sides of the anterior triangle this dense membranous stratum ends sharply by becoming firmly attached to the ischiopubic rami and the ischial tuberosities (Figs. 694, 695). In the middle line it is divided by the cleft of the vestibule; behind, it marks the line of division between the anal and urogenital portions of the perineum; here it curves upward around the superficial transverse perineal muscle to join the fascia of the urogenital diaphragm (Figs. 618, 694).

Superficial Perineal Compartment. The deep layer of the superficial perineal fascia, in attaching itself to the margins of the bones at the pelvic outlet, forms the floor of a definite pouch in the anterior or urogenital part of the perineum (open in the specimen's left half of Fig. 694); and in becoming continuous posteriorly with the urogenital diaphragm, the same fascia forms the hinder boundary of this triangular pouch, which has been conveniently named the superficial perineal compartment (superficial, or anterior, intra-aponeurotic space, or superficial perineal interspace). The roof, or superior boundary, is the inferior fascia of the urogenital diaphragm. Anteriorly the compartment is open in the sense that the contained space is continuous upward, onto the interval situated between the deep layer of the superficial fascia (Scarpa's) and the deep fascia covering the muscles of the anterior abdominal wall (note probe in Fig. 694). It is through this stratum that an exudate, or blood or extravasated urine dissects its way, other routes being closed through the strength of fascial continuities and attachments.

The compartment contains the erectile or cavernous bodies of the clitoris and their investing muscles; in addition, it is traversed by the vessels and nerves (Figs. 694, 695) which supply these structures, and by those which ultimately leave the space to reach the integument and the subcutaneous tissue of the labia. Through the compartment, in vertical direction and in the medial plane, pass the terminal portions of the urinary and the genital tracts, partially subdividing the space into two.

Erectile Tissue. It has already been stated that the only portions of the clitoris visible when the labia are retracted are the small conical end of the glans and the short body, the latter noticeable only as a low, vertical ridge in the integument covering the lower part of the symphysis pubis. The other constituents of the erectile tissue, with their investing musculature, are housed in the superficial perineal compartment and are brought into view only when the deep layer of the superficial perineal fascia is removed (Fig. 695). The erectile bodies are composed of an intricate, plexiform arrangement of vascular channels, confined in definite masses by tough fibrous tunics. When incised, the cut surface displays channels in the form of cavities, and hence the tissue is referred to as cavernous.

Together the cavernous or erectile bodies form the clitoris and are homologous, though in reduced and modified form, to the components of the penis in the male (Figs. 657, *a*; 658, *a*; 695). The constituent parts of the female organ are the paired corpora cavernosa and the paired vestibular bulbs—the latter joined anteriorly to the glans. Each corpus cavernosum clitoridis corresponds to a corpus cavernosum penis in the male, but is much smaller; and, duplicating the condition in the male, the two corpora cavernosa unite in front to form the body of the clitoris, diverging behind as the crura (each a *crus clitoridis*). The vestibular bulb (bulbus vestibuli) of either side corresponds developmentally to a lateral half of the urethral bulb (*bulbus urethralis* of *corpus cavernosum urethrae*) in the male, but with the difference that the halves in the female remain separate and enclose the space of the vestibule.

The laterally placed corpora cavernosa, through their union anteriorly, form the small, unpaired, cylindrical body of the clitoris. The body, which measures 2 to 3 cm. in length, is bent upon itself and tapers somewhat distally, where it is covered by the glans. Although the two cavernous bars are enclosed in a dense fascial coat (*fascia clitoridis*), some degree of separateness between the symmetrical halves is effected by the clitoridal septum. As the body of the clitoris hangs down in front of the pubic symphysis, it is provided with a suspensory

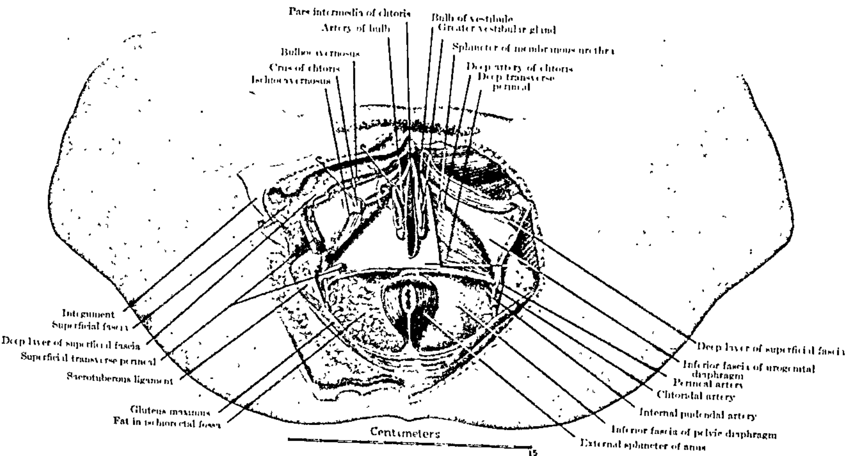


Fig. 695. FEMALE PERINEUM, SHOWING THE CONTENTS OF BOTH SUPERFICIAL AND DEEP COMPARTMENTS IN THE UROGENITAL DIVISION OF THE PERINEUM AND THE CONTENTS AND FASCIAL "ROOF" OF THE ISCHIORECTAL FOSSAS IN THE ANAL DIVISION.

On the right half of the urogenital triangle the crus of the clitoris and the bulb of the vestibule in the superficial compartment have been exposed by partial removal of their investing superficial perineal muscles; their arteries of supply (from the deep perineal compartment) have been demonstrated by drawing the cavernous bodies away from the inferior fascia of the urogenital diaphragm. On the left the inferior fascia of the urogenital diaphragm has been reflected to show the musculature in the deep perineal compartment. In the anal triangle, on the left side, the superficial (fatty) tissue has been removed from the ischiorectal fossa.

ligament that passes upward from it to the symphysis and onto the anterior abdominal wall. Behind, the two corpora cavernosa become completely separate as the crura, and are attached to the inner aspect of the pubic arch or, more specificially, to the rami of the ischium and the pubis (Fig. 699). Each is longer than the body, measuring about 4 cm. in length.

The rounded tubercle termed the glans, which constitutes the free extremity of the clitoris, possesses, like the homologous organ, a frenum and a prepuce (Fig. 693). It is not, however, traversed by the urethra. The glans of the clitoris fits over the rounded ends of the conjoined corpora cavernosa; yet it is not part of them, but rather an extension forward of the cavernous tissue of the vestibular bulbs, to which it is united under the body of the clitoris, by a slender, elongate mass of erectile tissue, the pars intermedia. The bulbs divide from this point of union anteriorly, passing backward and outward, with their medial surfaces in contact with the wall of the vestibule at its point of junction with the vagina. The separation of the bulbar mass into bilateral halves which surround the vestibule constitutes the dissimilarity between the bulb of the vestibule (female) and the bulb of the urethra (male). If the halves of the bulb in the female were brought into contact with each other, so that the vestibular outlet were closed and the urethra made to traverse the bulb, the body, the intermediate mass, and the glans of the clitoris, the corpus cavernosum urethrae of the male would thereby be reconstructed; this is tantamount to saying that the four portions of the medial mass of erectile tissue in the female find developmental and morphological equivalents in the male (*cf.* Fig. 657).

Each vestibular bulb is an oblong mass of erectile tissue, about 4 cm. long and 0.5 cm. wide. They are rounded behind, where they are in close contact with the greater vestibular glands, and pointed in front, where, narrowing considerably, they pass to the sides of the urethra and unite near the body of the clitoris. Behind, the medial surface of each is closely related to the lateral wall of the vaginal entrance, and may occasionally extend as far backward as the posterior wall of the vagina. Below, each extends to the base of the labium, and above it, is in contact with the inferior fascia of the urogenital diaphragm (Fig. 695).

CENTRAL TENDINOUS POINT. The cavernous bodies in the superficial perineal compartment are invested by thin sheets of musculature. The muscles which cover the bulbs, together with superficial transverse perineal muscle and the levator and external sphincter of the anus, converge to a fibrous point in the middle line of the perineum between the posterior labial commissure and the anus, and at the posterior limit of the superficial perineal compartment (Fig. 694). The so-called point is actually a common tendon of attachment for the several muscles which compose it (see p. 736). The structures at this tendinous point contribute to a neighboring and less definite wedge-shaped mass of fibrous and muscular tissue lying between the rectum and the vagina, called the perineal body. This body holds a relation to the front of the rectum comparable to that of the anococcygeal body behind.

SUPERFICIAL PERINEAL MUSCLES. The perineal muscles in the superficial group are arranged in three bilateral pairs, and are situated between the superficial fascia and the urogenital diaphragm, in association with the erectile bodies of the clitoris (Figs. 694, 695). The three muscles in either half of the superficial perineal compartment form the boundaries of a triangle, being placed in transverse, in oblique and in sagittal plane.

The posterior component, the superficial transverse perineal muscle, lies along the base of the urogenital triangle. It arises, as does the larger but homologous muscle in the male, by tendinous fibers from the medial and fore part of the tuberosity of the ischium. As a narrow, rounded slip, it runs medialward, to end between the anus and the vestibule, by fusing with its fellow of the opposite side and blending with other fibrous insertions that contribute to the central point of the perineum. The two transverse muscles serve to fix the central point; they are the stay around which the deep layer of the superficial fascia turns upward to join the inferior fascia of the urogenital diaphragm, and to close the superficial compartment behind.

Each ischiocavernosus muscle (*erector clitoridis*) is smaller than the corresponding muscle of the male. It is an elongate, oblong muscle, which fits groovelike over the unattached surfaces of the crus clitoridis (specimen's right half of Fig. 695). It is situated along the lateral boundary of the perineum, where it arises from the medial aspect of the ischial ramus, close to

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the tuberosity and about 2 cm. behind the origin of the crus; the fibers ensheathe and insert into the medial and inferior surfaces of the crus clitoridis, extending as far forward as the body. The two muscles serve to compress the crura and, by thus retarding the egress of blood, assist in producing erection of the clitoris.

In the male perineum the bulbocavernosus muscle is a single structure (Fig. 657, *b*); from an origin at the central tendinous point the muscle spreads over the bulb of the urethra, uniting on the superior aspect of the corpus cavernosum urethrae. In the female, on the contrary, the bulbocavernosus muscle (sphincter vaginae) is halved symmetrically by the vestibule, and each half is closely adapted to the lateral surface of a vestibular bulb, the bulbs representing an unfused and bifid corpus cavernosum urethrae of the male (Fig. 657, *a*). The fibers of both halves take origin from the central tendinous point, beneath the posterior labial commissure; they separate behind the vaginal orifice to pass forward on the walls of the vestibule; converging toward the midline, and narrowing into slender fasciculi, they extend in their insertion as far anteriorly as the dorsum of the body of the clitoris. They, too, act as constrictors of the erectile tissue.

VESTIBULAR GLANDS. The greater vestibular glands (Bartholin's glands) are the homologues of the bulbourethral (Cowper's) glands of the male. They are paired round or oblong bodies, attaining a length of about 1 cm. in their greatest diameter. They are placed at the posterior ends of the vestibular bulbs, into which their lobules may project (Fig. 695). Their long, simple ducts, which convey the mucous secretion, open into the vestibule, one on each side of the fossa navicularis; the orifices are visible to the naked eye just below the hymen, near the middle of the vaginal orifice.

TRIANGULAR SPACE. The bulbocavernosus muscle of each side forms the medial boundary of a small, triangular area, on the roof or superior aspect of which may be seen the inferior fascia of the urogenital diaphragm. The lateral boundary is formed by the ischiocavernosus muscle (Fig. 694); the superficial transverse perineal muscle lies posteriorly; the floor is formed by the deep layer of the superficial fascia. Running forward and medialward in the space are the posterior labial vessels and nerves and the transverse perineal vessels (*cf.* Fig. 654, male).

Urogenital Diaphragm. The deep fascia of the urogenital part of the perineum, like the superficial fascia of the same region, is double-layered. But, whereas the two layers of the superficial fascia are applied closely to each other, the two layers of the deep fascia are separated by important intervening structures (Fig. 695) and constitute the fibrous plates of the urogenital diaphragm (Fig. 696). The lower one of these is termed the inferior, the upper one, the superior fascia of the urogenital diaphragm (triangular ligament or urogenital trigone).

The two aponeurotic laminae (Fig. 696) are attached to the inner aspect of the pubic arch; they are blended together in front to form a sharp, transverse ligamentous band; behind, they produce an evenly rounded margin. The two fasciae enclose a slitlike pouch, which is the second or the deep compartment of the perineum (opened in Figs. 695, 696). This pouch contains the sphincter muscle surrounding the membranous part of the urethra, and the deep transverse perineal muscle; it is around the latter that the component layers of the diaphragm curve and join each other posteriorly. The entire diaphragm is a strong, musculomembranous partition of trapezoidal outline, stretched almost horizontally across the anterior half of the pelvic outlet. It is broader in the female than in the male, owing to the greater width of the pubic arch; it is less strong in the female, however, since it is pierced by the vaginal canal. The base, which is directed toward the anal part of the perineum, is drawn backward toward the midline at the central tendinous point (Fig. 694); the truncated apex is directed toward, but does not reach, the inferior aspect of the pubic symphysis (Fig. 696). The diaphragm measures about 12 cm. across the wide basal portion, and 5 cm. from base to apex; but the maximum depth of the enclosed space is less than 2 cm., and the perpendicular courses of the vagina and of the urethra through the compartment are correspondingly short (Fig. 617).

INFERIOR FASCIA OF THE UROGENITAL DIAPHRAGM. The more superficial of the two deep fascial layers of the urogenital region is known as the inferior fascia of the urogenital diaphragm (anterior, inferior or superficial

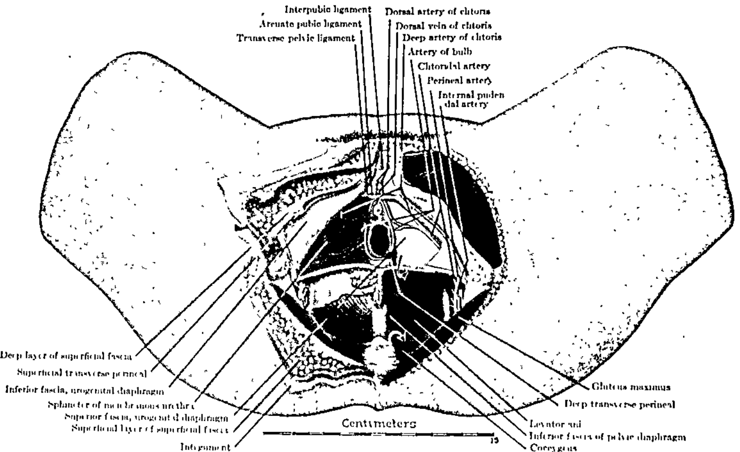


Fig. 696. FEMALE PERINEUM, DEMONSTRATING ESPECIALLY THE MUSCULAR AND FASCIAL CONSTITUENTS OF THE UROGENITAL DIAPHRAGM IN THE ANTERIOR DIVISION OF THE PERINEUM AND THE COMPARABLE STRUCTURES OF THE PELVIC DIAPHRAGM IN THE POSTERIOR DIVISION.

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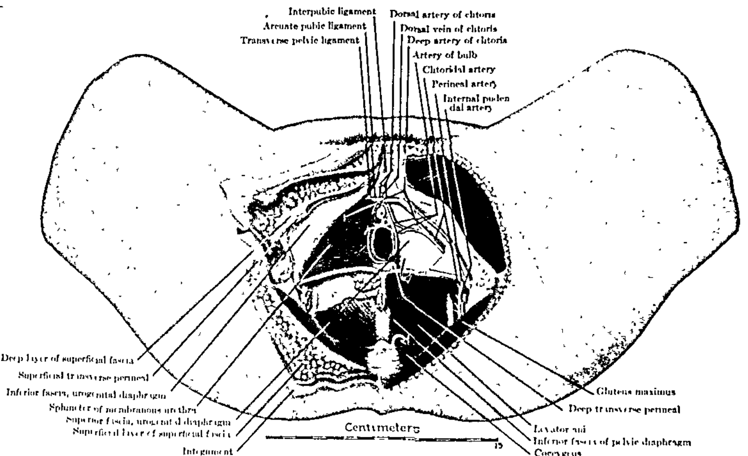


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layer of the triangular ligament; or inferior triangular ligament). Being interposed between the cavernous tissue and its musculature inferiorly, and the urethral sphincter superiorly, the fascia is at once the roof of the superficial, and the floor of the deep, compartment (*cf.* Figs. 694 and 695). Its shape and dimensions are those of the diaphragm previously described, of which it is the lower layer. It lies in the same plane as the rami at the pelvic outlet, its inferior surface facing somewhat anteriorly. The lateral margins are attached to the medial surfaces of the inferior rami of the ischium and the pubis, above the level of the attachment of the crura clitoridis; the median portion of the base is sent backward in the form of a fibrous projection to join the tendinous muscular attachments at the central point of the perineum; it is continuous in the basal part with the deep layer of the superficial fascia below (right half, Fig. 695), and the superior fascia of the urogenital diaphragm above (left half, Fig. 696); these continuities close the perineal compartments behind. The blunted apex is directed forward and unites with the superior fascial layer to form a ligamentous band, the transverse ligament of the pelvis (transverse perineal ligament) that passes from one side of the pubic arch to the other. On either side it blends with the arcuate pubic ligament (inferior pubic or subpubic ligament) except in the center, where the dorsal vein of the clitoris (Fig. 696), emerging from the superficial perineal compartment, passes upward and backward through an oval opening between the two ligaments to reach the pudendal venous plexus behind the pubic symphysis within the pelvic cavity (Fig. 617, p. 617).

The inferior fascia is not an unbroken layer. It is pierced in the median plane by the urethra and the vagina (Fig. 695); the point of perforation by the urethra is 1 to 1.5 cm. below the pubic symphysis, and the anterior limit of the vaginal opening is about 1 cm. further removed from the symphysis. On either side the base of the fascial compartment is pierced by the internal pudendal vessels and the pudendal nerves (Fig. 696), and in succession forward by the branches of these to the erectile tissue of the bulb, the crus and the glans (p. 733).

Deep Perineal Compartment. The deep perineal compartment (interspace or intra-aponeurotic space) is the pouch between the two layers of the deep fascia in the urogenital triangle of the perineum (opened in Fig. 695). It contains the deep transverse perineal muscle, the sphincter muscle surrounding the membranous part of the urethra, and the pudendal vessels and nerves.

SPHINCTER MUSCLE. The sphincter muscle of the membranous urethra (compressor urethrae) is enclosed between the fasciae of the urogenital diaphragm, and surrounds the entire length of the membranous portion of the urethra (Fig. 696). The innermost fasciculi form an interrupted ring of fibers that embrace the urethra. The external fibers have a bony origin, arising on each side of the perineum from the inner aspect of the ischiopubic ramus for a distance of approximately 2 cm.; the fibers are also attached to the apposed surfaces of the two fascial laminae of the diaphragm. As they approach the median plane, the anterior fibers pass in front of and behind the urethra, uniting with the muscle of the opposite side, or joining it in a tendinous raphe; the middle group of fibers is attached to the wall of the vagina, while the posterior ones may intermingle in the middle line or unite in a raphe. The muscle is a sphincter, serving to constrict the urethra and to flatten the vaginal walls.

DEEP TRANSVERSE PERINEAL MUSCLE. The deep transverse perineal muscle (constrictor urethrae, or compressor urethrae when considered together with the preceding muscle) lies in the same plane as the urethral sphincter, with the posterior border of which it is so closely blended as to be scarcely separable from it (Fig. 695). On each side the muscle takes origin through a short tendon from the ramus of the ischium; the two expand somewhat as they run medialward, where they become tendinous and interweave in the middle line. Some of the anterior fibers, like those of the sphincter, insert into the vaginal wall; others, passing backward, no longer remain confined to the compartment, but end in the perineal body. Through its action as a tensor the muscle assists in supporting the pelvic floor.

SUPERIOR FASCIA OF THE UROGENITAL DIAPHRAGM. The upper lamina of the two-layered deep fascia in the urogenital triangle is termed the superior fascia of the urogenital diaphragm (posterior, superior or deep layer of the triangular ligament). It forms at once the roof of the deep perineal compartment

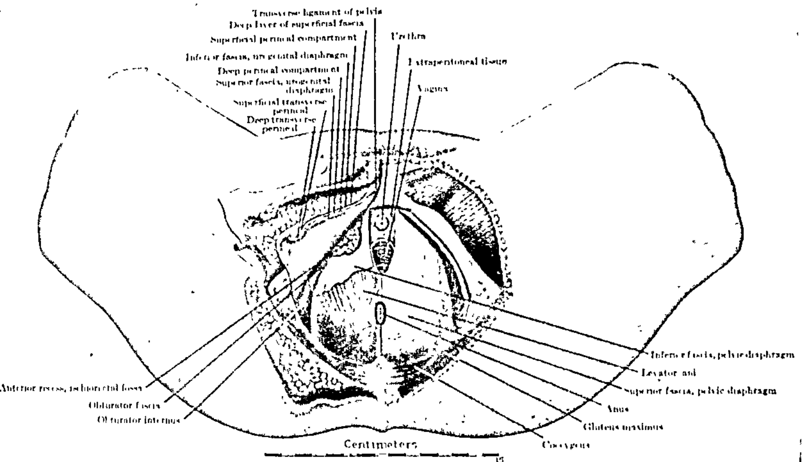


Fig. 697. FEMALE PERINEUM, IN DEEP DISSECTION; SHOWING THE THREE CONSTITUENT ELEMENTS OF THE PELVIC DIAPHRAGM.

On the right the inferior fascia of the pelvic diaphragm and the levator ani muscle are shown; on the left the musculature has been removed to show the superior fascial layer of the diaphragm. Some fatty tissue remains in the anterior recess of the right ischiorectal fossa.

On the subject's right half the fascial layers which bound the two perineal compartments, together with their muscular contents, have been reflected lateralward. The constituent elements are additive to those encountered in the anal division of the perineum.

Fig. 698. FEMALE PERINEUM; SKELETAL AND LIGAMENTOUS BOUNDARIES.

The inferior aspect of the female pelvis, showing bones and ligaments, and, on the subject's left, the muscles of the thigh and of the buttock. From anterior to posterior the following structures form the boundaries of the pelvic outlet: pubic arcuate ligament (at the pubic symphysis); the inferior ramus of the pubis; the inferior ramus of the ischium and the tuberosity of the latter bone; the sacrotuberous ligament (superficial to the sacrospinous ligament); and the coccyx.

(left half, Fig. 696) and the floor of the anterior recess or extension of the ischiorectal fossa on either side of the midline. Although the superior and the inferior diaphragmatic fascial layers are intimately connected with each other behind and in front, the deep layer is strictly a medially directed lamella from the parietal portion of the pelvic fascia, since it is derived from the fascial covering of the obturator internus muscle along the line of the latter's attachment to the periosteum of the ischiopubic rami (right half, Fig. 697).

Anteriorly the superior fascia of the urogenital diaphragm, conjoined with the inferior layer, forms the transverse ligament of the pelvis (Figs. 696, 697); at the sides, as stated, it meets the obturator fascia; behind, it is again continuous with the inferior fascia around the deep transverse perineal muscle, and, through the medium of the inferior fascia, with the deep (Colles') layer of the superficial fascia. Medially and above, it joins the fascial covering on the under surface of the levator ani muscle (Fig. 696).

Anterior Recess of the Ischiorectal Fossa. In the urogenital half of the perineum, above the

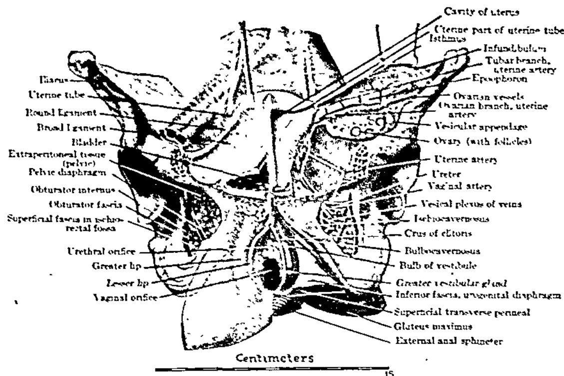


Fig. 699. STRUCTURES OF THE FEMALE PELVIS AND PERINEUM, SEEN IN DISSECTION FROM THE FRONT.

The dissection demonstrates the following features: the broad ligament (on the specimen's right); the cavity of the uterus and the lumen of the uterine tube (on the opposite half); the ovarian, uterine and vaginal arteries; the urinary bladder (opened by median sagittal and coronal sectioning); the parietal and diaphragmatic muscles of the pelvis (seen through the opened obturator foramen on the specimen's right), the contents of the superficial perineal compartment (on the opposite half).

The broad ligament, which normally rests upon the urinary bladder in front, crosses the pelvic cavity in the form of a quadrangular transverse septum. Two secondary folds originate from the broad ligament, one from each surface; an anterior fold invests the round ligament of the uterus; a posterior fold covers the proper ligament of the ovary and is prolonged to the gland as the mesovarium.

The cavity of the body of the uterus, when seen in frontal section, has the form of a triangle all sides of which are convex inward. Below, at the constricted internal orifice (corresponding to the isthmus externally), the cavity becomes continuous with the cervical canal; above, the cavity is continuous with the lumen of the uterine tube. The spindle-shaped canal of the cervix opens below into the vagina at the external orifice of the uterus (see also Fig. 614).

The uterine ostium of the uterine tube is a minute orifice in the muscular wall; the next portion, the isthmus, is thick-walled and relatively narrow: The lumen of the isthmus gradually increases in diameter as it passes lateralward to become continuous with the ampulla, which is thin-walled and dilatable. The ampulla, which is the longest and most capacious portion of the uterine tube, is flexuous, usually somewhat convoluted; it leads into a trumpet-shaped expansion, termed the infundibulum, the internal surface of which is thrown into folds. These plications are continuous medially with those of the ampulla; laterally they are prolonged to the end of the tube where they project in the form of long, irregular processes, the fimbriae.

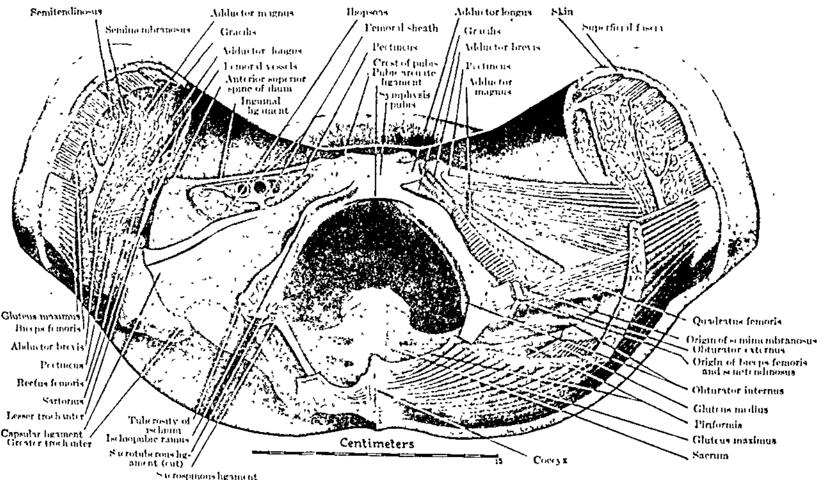


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generally, namely, the integument, the fatty pannicle, and the deep fascial investment of the muscles. In the anal triangle the diaphragmatic fascial layer on the under surface of the levator ani muscle is the third reached as the dissector works inward; in the urogenital triangle the same layer is the ninth stratum encountered (Fig. 700).

Pelvic Diaphragm. The pelvic diaphragm forms the conical or funnel-shaped musculotendinous partition between the perineum below and the pelvic cavity above. It is made up of two pairs of muscles, the levatores ani and the coccygei, invested on the perineal and the pelvic surfaces by a layer of fascia (Figs. 696, 697). From the pelvic wall on each side the muscles pass downward toward the median line, there to meet each other and fuse, or to surround the terminal portions of the anus, the vagina and the urethra. The concave surface of the diaphragm is directed toward the pelvic cavity (Figs. 618, 619, pp. 637, 638).

FASCIAL LAYERS. The inferior fascial layer (anal layer of the diaphragmatic fascia, anal fascia or ischiorectal fascia) covers the under surface of the pelvic diaphragm (Fig. 695); it faces downward and lateralward. Superiorly it springs from the parietal layer of fascia covering the obturator internus muscle, along the line of origin of the levator ani muscle; medially it meets the fasciae of the anal sphincters; anteriorly it blends with the superior fascia of the urogenital diaphragm, posteriorly with the fascia on the inner or deep surface of the gluteus maximus muscle.

The superior fascial layer (visceral layer of the diaphragmatic fascia) covers the upper surface of the pelvic diaphragm (Fig. 697), following the line of origin of the levator ani muscle and extending along the lateral pelvic wall in a tendinous arch from the pubic symphysis to the iliac spine (Fig. 623). Therefrom it extends downward and medialward to cover the muscles of the diaphragm and to invest closely the viscera in the lesser pelvis. The viscera, with their thickened fibrous tunics, are in turn lodged in an areolar tissue basis (right half, Fig. 700). This packing, which intervenes between the fascia and the peritoneum of the pelvis, is likewise the bed through which course the visceral branches of the blood vessels, nervous plexuses and lymphatic channels (specimen's right half, Fig. 616). It ends superiorly at the peritoneum, to the deep surface of which it is attached.

NERVES. The pudendal nerve is the chief source of muscular and cutaneous innervation in the perineum. The nerve of each side represents the smaller portion or band of the pudendal plexus; the larger component, the sciatic band, continues as the nerve of the same name and supplies the lower extremity. The pudendal nerve is derived from the anterior rami of the second, third and fourth sacral nerves; it accompanies the internal pudendal artery and vein, leaving the pelvis through the greater sciatic foramen and entering the ischiorectal fossa of the perineum through the lesser sciatic foramen (Fig. 623). As the pudendal nerve enters the ischiorectal fossa, its first important branches are the inferior hemorrhoidal nerves, which accompany the hemorrhoidal vessels medialward to supply the external anal sphincter muscle and the integument around the anus. The pudendal nerve then divides into two terminal branches, the perineal and the dorsal nerve of the clitoris, near the posterior margin of the urogenital diaphragm.

The perineal nerve sends superficial branches forward, which enter the superficial perineal compartment as the posterior scrotal nerves, passing in company with the corresponding arteries to the skin of the labium and of the anterior part of the perineum (Fig. 694). The deep division of the perineal nerve is mainly muscular, inasmuch as it supplies all the muscles in both the anal and the urogenital portions of the perineum. In the anal triangle, fibers are sent to the levator ani and to the external anal sphincter muscles. The nerve then pierces the base of the urogenital diaphragm; entering the deep perineal compartment, it is distributed to the deep transverse muscle and the urethral sphincter. Other fibers, reaching the superficial compartment, supply the superficial transverse muscle, the ischiocavernosus and the bulbocavernosus muscles (*cf.* arteries, Figs. 694 to 696).

The dorsal nerve of the clitoris enters the deep compartment at the anterior end of the canal of Alcock in the obturator fascia; with the dorsal artery it traverses this space and pierces the inferior fascia of the urogenital diaphragm, coursing forward on the dorsum of the clitoris to the glans; it contributes fibers to the sympathetic cavernous plexus that sup-

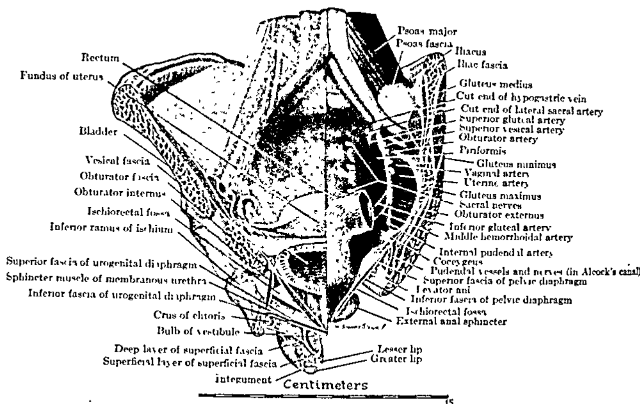


Fig. 700. STRUCTURES OF THE FEMALE PELVIS AND PERINEUM, FROM INTEGUMENTARY TO PERITONEAL LEVEL IN BOTH THE UROGENITAL AND ANAL DIVISIONS.

Coronal section on the specimen's left through the anal, on the right through the urogenital, part of the perineum. On the right the peritoneum and the fascial layers are intact; the superficial fatty tissue has been removed from both ischiorectal fossae.

In the anal division of the perineum (in the natural state) the tissue of the fatty pannicle, or superficial fascia, is the only layer which intervenes between the integument and the fascia which covers the inferior surface of the levator ani and coccygeus muscles. On the contrary, in the urogenital part of the perineum, a complex succession of additional layers (related to the 2 compartments) is encountered between the skin and the pelvic diaphragm. These constituents are the following: the deep, membranous layer of the superficial fascia (Colles' fascia); the erectile tissue and investing or related muscles in the superficial perineal compartment; the inferior fascia of the urogenital diaphragm; the muscles (urethral sphincter and deep transverse perineal) of the urogenital diaphragm, occupying the deep perineal compartment; the superior fascia of the urogenital diaphragm; the fatty tissue in the anterior recess of the ischiorectal fossa.

superior fascia of the urogenital diaphragm on either side, the fat-filled ischiorectal fossa extends forward for a distance of about 5.5 cm. The space (opened in Fig. 697) resembles, in shape, a triangular prism, the base of which adjoins the larger area in the anal part of the perineum. The lateral boundary of the space is formed by the parietal fascia covering the obturator internus muscle (Fig. 697); the superior boundary is the inferior fascia of the pelvic diaphragm investing the under surface of the levator ani muscle; the inferior boundary is the fascia, likewise diaphragmatic, on the upper surface of the urethral sphincter.

It should now be clear that, whereas the fatty superficial fascia of the ischiorectal fossa in the anal region is the only layer between the skin below and the fascia of the pelvic floor above, in the urogenital triangle a series of important additional strata (turned outward in Fig. 697, viewed in coronal section in Fig. 700) intervene between the two; these layers are as follows: the deep membranous layer of the superficial fascia, the erectile tissue and the muscles of the superficial compartment, the inferior fascia of the urogenital diaphragm, the musculature in the deep compartment, the superior fascia of the urogenital diaphragm, and the fatty tissue in the anterior recess of the ischiorectal fossa. Were these strata not present, the succession of layers in the two subdivisions of the perineum (anal and urogenital) would be similar. Moreover, they would be comparable to that existing over the body

pudendal nerve. Fibers from the fifth lumbar and first and second sacral nerves accompany the pudendal nerve through the sciatic foramina, from the pelvis to the perineum, and there innervate the obturator internus muscle.

Surgical Considerations

The intimate connection of the vestibular glands (of Bartholin) with the bulb explains the hemorrhage sometimes following extirpation of these glands. The trauma of labor may rupture the bulb and cause extensive hematomas which undergo thrombosis.

The *major vestibular glands* (of Bartholin) lie one on each side of the vaginal orifice deep to the bulb, but superficial to the urogenital diaphragm. These glands are located deep to the posterior extremities of the labia majora. Enlarged glands, palpated between the thumb placed over the labium majus and the forefinger in the vagina, have the resistance of an indurated lymph node. The duct runs through the base of the labium minus to open in the groove separating the labium minus from the hymen at the junction of the posterior and middle thirds of the depression. By incising the labium minus a little lateral to this groove, the vascular bulb can be avoided and the gland located on the inferior fascia of the urogenital diaphragm. These glands are functionally active during sexual excitement, their secretion acting as a lubricant. Infection, almost exclusively gonococcal, reaches their branching tubules through the ducts, patent during intercourse, and may lie dormant, later to result in abscess or cyst formation. An abscess should be incised downward. Cysts or chronically infected glands are best treated by complete excision (Fig. 701).

URETHRA. Owing to its relations to the external genitals, the urethral orifice is exposed constantly to infection from without. Its position under the resistant pubic arch renders the urethra liable to damage from prolonged pressure in labor or in pelvic tumors. It is well protected from external injury by its position between the thighs.

An important barrier to bacterial infection of the urinary tract by way of the urethra is the delicate mucous folds, the urethral labia, which meet over the urethral orifice. These are seen best when the hymen is intact, or in multiparae. They are developed in association with the hymen and project beyond the urethral orifice somewhat as the labia minora cover the introitus.

The central point of the perineum is a fibromuscular tendinous mass formed from

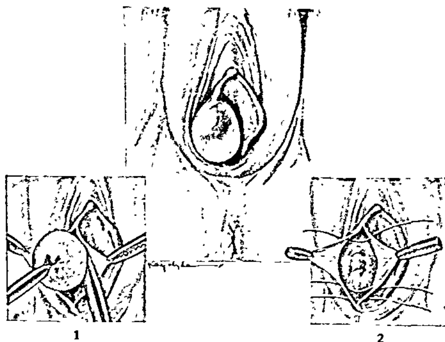


Fig. 701. BARTHOLIN'S GLAND CYST AND THE STEPS IN ITS REMOVAL.
1, Cyst enucleated; 2, pedicle ligated—sutures placed for closure of incision.

plies all the erectile tissue (*cf.* arteries, Fig. 695).

The integument of the perineum, in addition to the fibers received from the posterior labial nerves, is also supplied by the following: the anterior labial branches of the ilio-inguinal nerve; the external spermatic branch of the genitofemoral; the perineal branches of the posterior femoral cutaneous nerve; the perforating cutaneous branches of the second and third sacral nerves; the perineal branch of the fourth sacral, and the anococcygeal nerves.

The ilio-inguinal nerve is derived chiefly from the first lumbar nerve, through the lumbar plexus (Fig. 565); within the abdomen it emerges from the lateral border of the psoas major muscle, and crosses the quadratus lumborum muscle to enter the pelvis major. Here it extends forward on the iliacus, to gain the anterior abdominal wall, the musculature of which it pierces to gain the subcutaneous inguinal ring and the front of the thigh, where it sends the anterior labial nerves to the integument of the mons and the labia.

The genitofemoral (genitocrural) nerve has a similar origin; it usually follows the course of the round ligament through the length of the inguinal canal, and gives cutaneous fibers to the labium.

The posterior femoral cutaneous (small sciatic) nerve arises from the sacral plexus, receiving fibers from the first to third sacral nerves (Fig. 566); it leaves the pelvis through the greater ischiadic foramen below the piriformis muscle; descending beneath the gluteus maximus muscle, it passes downward on the back of the thigh beneath the fascia lata; the perineal rami, destined to supply the skin of the perineum, pierce the fascia a short distance anterior to the ischial tuberosity, and course forward and medialward.

The second and third sacral nerves of the sacral plexus send cutaneous fibers through the sacrotuberous ligament, which, in the main, turn around the inferior border of the gluteus maximus muscle to supply the skin of the buttocks; some of the fibers, however, turn forward into the perineum. The perineal branch of the fourth sacral nerve enters the ischiorectal fossa by passing through the coccygeus muscle of the pelvic diaphragm; it supplies the skin of the perineum between the anus and the coccyx. The anococcygeal nerves are derived from the fourth and fifth sacral and the coccygeal nerves, which unite along the coccyx to form a plexiform cord; small branches pierce the sacrotuberous ligament, supplying the skin behind the anus in the coccygeal area.

The urinary bladder, the internal organs of generation, and the rectum are supplied by the pelvic part of the hypogastric plexus (plexus hypogastricus) of the sympathetic system of nerves. It receives peripheral branches from the four ganglia (ganglia sacralia) on the pelvic portion of each sympathetic trunk, and gray communicating rami from the second to the fourth sacral (spinal) nerves. The nerves form a network which is continuous behind with the hypogastric plexus, and from which fibers extend forward along the course of each hypogastric artery, to be distributed to the pelvic organs supplied by the artery's visceral branches (*cf.* Figs. 569, *a;* 570, *b*). The entire plexus is thus subdivided into the secondary plexuses. The most posterior of these is the middle hemorrhoidal plexus, which is distributed to the rectum. The uterovaginalis plexus is placed in an intermediate position within the pelvis minor; it follows the course of the uterine artery, and then ascends between the layers of the broad ligament to spread out upon both surfaces of the uterus. The plexus is large, corresponding to the high development of the muscular layer of the uterus, which receives most of its fibers. Fibers are also sent to the walls of the vagina and to the erectile tissue of the bulb. The vesical plexus is associated with the urinary bladder. The fibers of this plexus accompany the vesical arteries to the bladder, and are distributed chiefly to its muscular layers. The sympathetic fibers which supply the ovary are not derived from the sacral ganglia, but are contributed by the renal and aortic plexuses; they accompany the ovarian artery in its descent into the pelvis, and enter the ovarian substance through the hilum.

The musculature which forms the walls and the floor of the pelvis minor receives its innervation from the ventral divisions of the last lumbar and the sacral nerves. The piriformis muscle receives twigs from the first and second sacral nerves, which enter the pelvic surface. The coccygeus and levator ani muscles are supplied by branches of the third and fourth sacral nerves upon their pelvic surface; the latter muscle also receives, upon its perineal aspect, fibers from the perineal branch of the

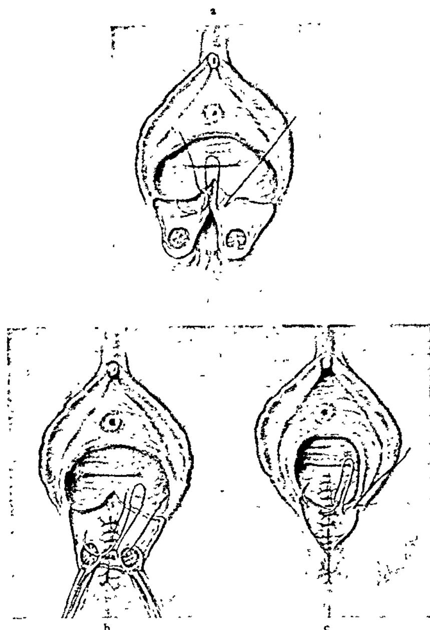


Fig. 703. REPAIR OF THIRD-DEGREE PERINEAL LACERATION.

a, Two rows of submucosal stitches are used to close the rectal mucosa, everting the edges into the rectum. *b*, The torn ends of the external sphincter are reapproximated with interrupted sutures in the fascial sheath. *c*, The episiotomy repair is completed in the usual manner. (From Fulsher and Fearl: Am. J. Obst. & Gynec., 69: 786–93, 1955.)

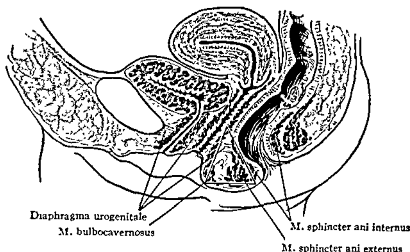


Fig. 702. MIDSAGITTAL SECTION THROUGH THE FEMALE PELVIS AND PERINEUM TO SHOW THE STRUCTURES INJURED IN PERINEAL TEARS.

The structures within the obstetrical perineal triangle frequently are lacerated.

the crisscrossing fibers of the anal sphincters, constricting muscles of the vagina, transverse perineal muscles and the levator ani muscles. In pregnancy, because of the inherent elasticity of this composite, it gradually distends to sustain, direct and support the fetus. When the elasticity is insufficient, or the exerting force too strong or too precipitous, the perineal body ruptures (Fig. 702). The tear may involve only the superficial muscle layers and leave the vulva and skin intact. More frequently the fourchette of the vagina is destroyed, and the laceration extends toward the anus (incomplete tear). Infrequently the laceration may extend from the vagina into the anal canal (complete tear). When the tear involves the rectovaginal septum and weakens the pelvic floor, it relaxes the pelvic outlet and predisposes to a rectocele or prolapse (Fig. 672).

REPAIR OF THIRD-DEGREE LACERATION IN MODERN OBSTETRICS. This is a less frequent injury from delivery now than previously because obstetrics is commonly practised today in hospitals in the United States, and midwifery is practically nonexistent. Episiotomies also have reduced the incidence of third-degree tears. When they occur, however, immediate repair is a relatively simple coaptation of the torn parts (Fig. 703). The thirty-seven reported by Fulsher and Fearl all healed without fistulas or impaired anal control.

PROLAPSE OF THE URETHRAL MUCOSA. Occasionally the urethral mucosa becomes loosened from its submucosal attachment, and a part protrudes through the external orifice, forming a small, pale, bluish mass which may become edematous and sometimes gangrenous. This protruding mass is covered on all sides by sensitive, easily bleeding mucous membrane.

URETHRITIS. Inflammation of the urethra is a common and often overlooked condition in women, frequently misdiagnosed as cystitis. In acute gonococcal infections, urethritis tends to disappear spontaneously with the disappearance of the disease elsewhere, unless it persists in and recurs from a chronically infected paraurethral gland (of Skene). A purulent exudate at the urethral meatus usually is indicative of "skenitis." When inflammation in the paraurethral glands is overlooked, treatment of the accompanying leukorrhea may be misdirected toward the cervix. A persistent infection in these glands should be treated by cauterization through the ducts.

URETHRAL CARUNCLE. A caruncle is a connective tissue tumor (polyp), rich in blood vessels and nerve filaments, attached to the margin of the urethral orifice by a broad base. These tumors are intensely red, exquisitely tender, and difficult to distinguish from prolapsed urethral mucous membrane, save by tissue examination. Effective treatment of this excrescence requires complete extirpation. Anything short of complete removal almost always is followed by recurrence.

The vestibule of the vagina is enclosed between the labia minora and extends from the clitoris anteriorly to the frenulum posteriorly (Fig. 704). In its floor are the urethral and

vaginal orifices, the minute openings of the paraurethral ducts (of Skene), and the ducts of the major vestibular glands (of Bartholin). The *urethral orifice* occupies a conspicuous elevation (urethral papilla) which lies about 2 cm. behind the clitoris. The *vaginal orifice* in the virgin is narrowed by a duplication of mucous membrane, the *hymen*, which, after rupture, is represented by irregular projections into the vaginal orifice, the *hymeneal caruncles*.

Imperforate Hymen. Imperforate hymen may not be recognized until puberty, at which time the patient may experience all symptoms of menstruation save the escape of menstrual flow from the genital canal. The menstrual fluid dilates the vaginal canal. The first symptom may be urinary retention from pressure of the dilated vagina on the urethra. Further accumulation may cause dilatation of the uterine canal and even of the uterine tubes, with escape of menstrual products into the peritoneal cavity.

The accumulation of the menses in the vagina is termed *hematocolpos* (Fig. 647); if the menstruum then dilates the uterine cavity, the condition is termed *hematocolpometra*. If the tubes also become dilated, the condition is termed *hematocolpometrasalpinx* (Fig. 705). The treatment is free incision of the hymen.

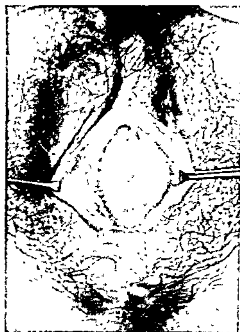


Fig. 705. Imperforate hymen with hematocolpometrasalpinx.

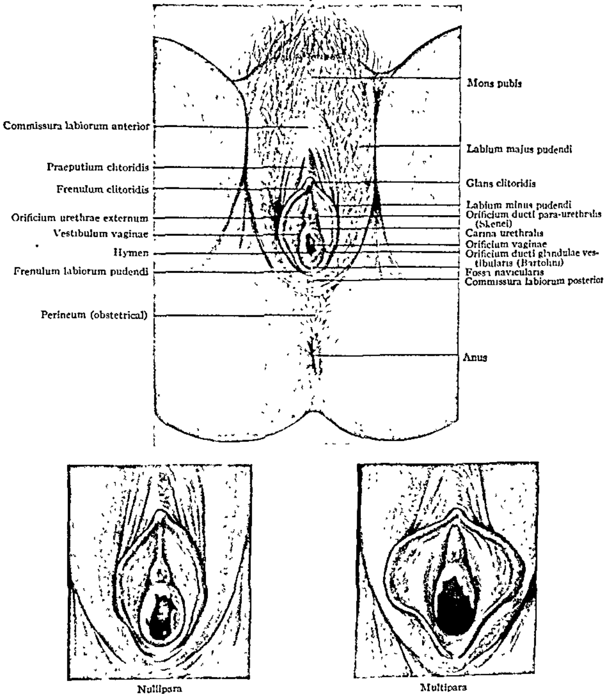
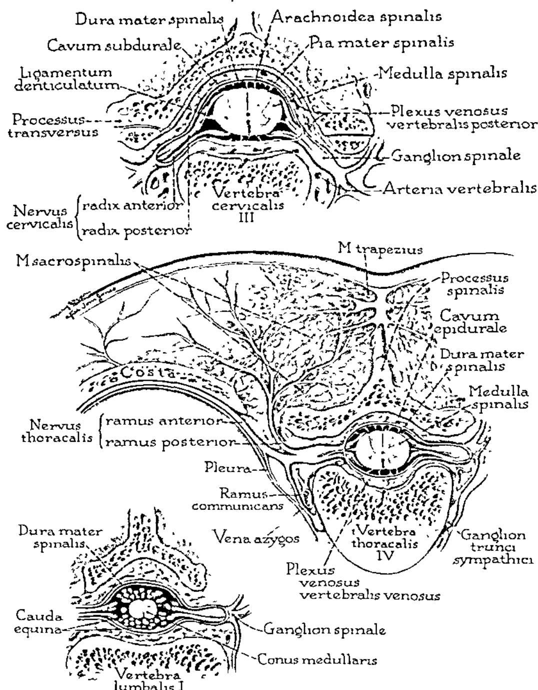


Fig. 704. PERINEAL REGION IN THE FEMALE TO SHOW THE EXTERNAL GENITALS.

PART VII

The Vertebral Column and Spinal Cord



SPINAL CORD AND MENINGES AT THE FOLLOWING VERTEBRAL LEVELS: THIRD CERVICAL; FOURTH THORACIC; FIRST LUMBAR (AFTER TOM JONES).

CHAPTER 24

Vertebral Column

The spinal column is the central pillar of the body, through which many varied and complicated motions are combined (Fig. 706). It functions as two segments: the *superior*, long, flexible portion supports the head and carries the thorax and abdomen; the *inferior*, short, rigid, pelvic portion carries the lower extremities. Through the pelvic portion the weight of the body and the effect of shock are transmitted to the lower extremities.

The spinal column is comprised of the vertebrae, enveloped and bound together by a series of well distributed and strongly resistant ligaments, and balanced one upon the other by strong active musculature. The vertebrae articulate anteriorly through their bodies by the interposition of fibrocartilaginous disks and posterolaterally through articular processes. The column has a considerable range of movement, but movement beyond its normal range unduly compresses the vertebral disks and may permit fracture of the related bodies, with consequent injury to the spinal cord or its root nerves.

The *visceral*, *anterior* or *flexor surface* of the pillar presents in the midline a cylindrical

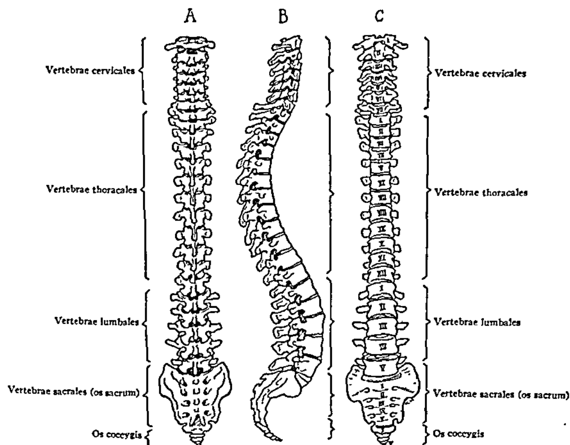


Fig. 706. POSTERIOR, LATERAL AND ANTERIOR VIEWS OF THE SPINAL COLUMN.

(*vertebral*) *canal*, which encloses the spinal cord and its coverings (Frontispiece, Part VII). Between each pair of vertebrae, on either side, are apertures, the intervertebral foramina, for the transmission of spinal vessels and nerves (Fig. 707). Fractures of the bodies, arches or their processes may injure the cord or its nerve roots. Hemorrhages consequent upon fracture may cause pressure on the cord, with resulting paralyses.

Vertebral Characteristics. The central bony pillar or spine extends from the base of the skull to the inferior extremity of the trunk (Fig. 706). It is divided into four topographical regions: the cervical, thoracic and lumbar, embraced in the superior segment, and the sacrococcygeal in the inferior segment. The component vertebrae are morphologically equivalent and conform to a real type.

Of the thirty-three skeletal units in the vertebral column, twenty-four remain movable, while nine become fixed through fusion. Of the nine fused elements, the sacrum contains five, the coccyx four. These represent the caudal portion of the vertebral column. At the opposite, or cranial, end of the column less profound alteration occurs, to modify the first and second cervical vertebrae, atlas and axis (or epistropheus), respectively.

A typical vertebra (Fig. 708, *a*) is composed of two main portions, namely, a body (centrum) and an arch (arcus). The arch consists of two pedicles (roots, radices) and a pair of plates (laminae). The space enclosed by the body and the arch is the vertebral canal. The arch supports seven processes: four articular, two transverse and one spinous.

The vertebral bodies increase progressively in size from cervical to lumbar regions. Thus, in a typical cervical vertebra, the body is relatively small (Fig. 708, *b*); the corresponding part is larger in a thoracic vertebra (Fig. 708, *c*), and larger still in a lumbar vertebra (Fig. 708, *a*, *e*). The bodies of the sacral vertebrae are fused (Fig. 709, *j*, *k*); in the coccyx they are rudimentary (Fig. 709, *l*).

Considering next the several features of the arch, it may be noted that the root of a typical cervical vertebra is short and is directed backward. In the sacrum the roots are not distinguishable (Fig. 709, *k*); in the coccyx they are wanting.

The plates of a typical cervical vertebra are long (Fig. 708, *b*). Those of the first cervical

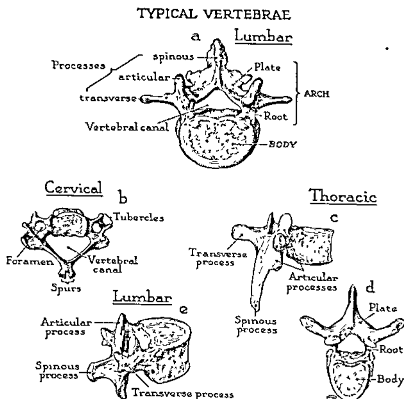


Fig. 708. TYPICAL VERTEBRAE OF THE CERVICAL, THORACIC AND LUMBAR DIVISIONS OF THE SPINAL COLUMN

column comprised of the superimposed vertebral bodies (Fig. 706, *C*). This surface is in relation throughout with the viscera, and supports and protects them and their vessel and nerve supply; it is separated from them by a cellular layer which occupies the prevertebral space. Into and along this space extend abscesses from Pott's disease; the course of extension depends upon the anatomy of the various regions. The abscess may bulge into or present at the pharynx (p. 159), descend into the neck, bulge into the supraclavicular fossa, or follow the nerve plexuses into the axilla. It may extend into the mediastinum and follow intercostal nerves into the thickness of the chest wall; it may open into the abdomen or the rectum, or other abdominal viscus, or extend into the gluteal region and thence into the posterior region of the thigh and the popliteal space.

The *posterior* or *extensor surface* of the pillar descends along the midline of the body posteriorly. It is made up of the superimposed spinous processes, laminae, transverse processes, pedicles and articular processes of the vertebrae with their retrospinal soft parts (Fig. 706, *A*). The bony part of this portion, covered only by the skin and a single heavy layer of muscles, is relatively superficial and therefore is accessible to clinical examination and surgical intervention. For the same reason these bony structures are exposed to direct trauma, buckling and crushing. The products of tuberculous inflammation in these bony parts present or localize promptly at the skin.

Between these two surfaces is the *spinal*

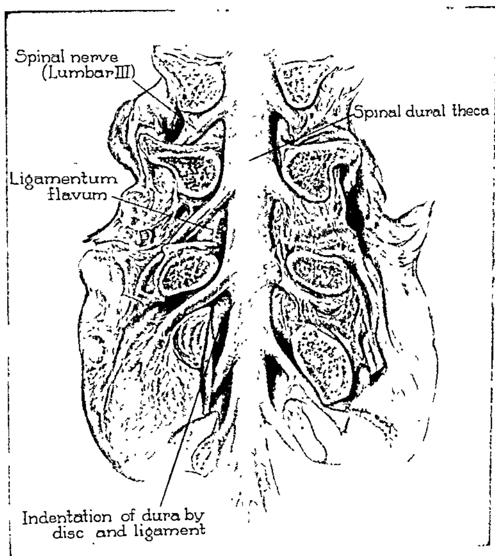


Fig. 707. POSTERIOR VIEW OF THE LUMBAR AREA OF THE VERTEBRAL CANAL WITH ITS CONTENTS. (From Naffziger, Inman and Saunders: Surg., Gynec. & Obst., 66: 288-99, 1938.)

(*vertebral*) *canal*, which encloses the spinal cord and its coverings (Frontispiece, Part VII). Between each pair of vertebrae, on either side, are apertures, the intervertebral foramina, for the transmission of spinal vessels and nerves (Fig. 707). Fractures of the bodies, arches or their processes may injure the cord or its nerve roots. Hemorrhages consequent upon fracture may cause pressure on the cord, with resulting paralyses.

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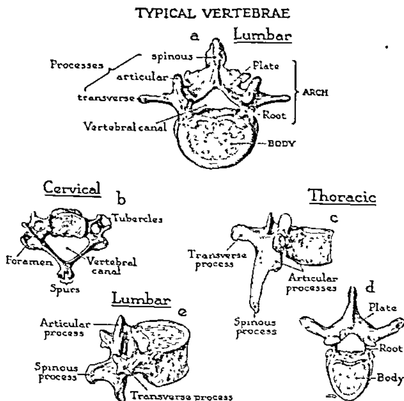


Fig. 708. TYPICAL VERTEBRAE OF THE CERVICAL, THORACIC AND LUMBAR DIVISIONS OF THE SPINAL COLUMN

form a slender arch (Fig. 709, *f*). The plates are short and strong in the lumbar vertebrae (Fig. 708, *a*), fused in the sacrum (Fig. 709, *k*) and lacking entirely in the coccyx.

In a typical cervical vertebra the articular processes are flat; in the thoracic region they stand vertically and frontally (Fig. 708, *c*, *d*). In the lumbar vertebrae their surfaces lie in a sagittal plane (Fig. 708, *a*). On the dorsum of the sacrum the processes are fused to form the articular crest on each side (Fig. 709, *k*); they are absent in the coccyx.

The transverse processes of a typical cervical vertebra are tuberculate, perforate, short and laterally directed (Fig. 708, *b*). In a typical thoracic vertebra the transverse processes are faceted, long and thick and backward directed (Fig. 708, *c*); on a lumbar vertebra they are long and slender and horizontal (Fig. 708, *e*). On the sacrum the transverse processes are atrophic, being represented by the inconspicuous lateral crests (Fig. 709, *k*). On the coccyx only the first piece bears a transverse process, and then only in rudimentary form (Fig. 709, *l*).

The spinous process of a typical cervical vertebra is short and bifid (Fig. 708, *b*); on the first cervical it is suppressed, being a mere tubercle on the posterior arch (Fig. 709, *f*). The spinous process of a thoracic vertebra is

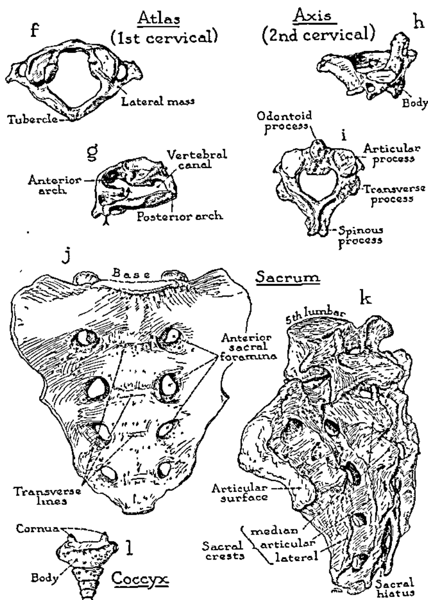


Fig. 709. ATYPICAL, SEPARATE VERTEBRAE (ATLAS AND AXIS); FUSED VERTEBRAE (SACRUM AND COCCYX).

elongate and sloping, or even vertical (Fig. 708, *c*). In the lumbar region the spinous process is thick and broad, quadrilateral and horizontal (Fig. 708, *e*). On the sacrum the several processes become fused to form the median crest (Fig. 709, *k*). Since no portion of the arch persists on any of the coccygeal segments, the spinous processes are wanting.

The vertebral canal of the first cervical vertebra is large and quintagonal (Fig. 709, *f*). At the middle cervical level the canal is wide and triangular in outline (Fig. 708, *b*); in a thoracic vertebra it is small and almost circular (Fig. 708, *d*). In a lumbar vertebra the canal is also narrow, but again assumes a triangular outline (Fig. 708, *a*). On the last piece of the sacrum the canal is incomplete behind, at the sacral hiatus (Fig. 709, *k*); on the coccyx it is deficient on the sides as well as behind.

DEVELOPMENT. Each vertebra is developed through three *primary centers* of ossification, one for the body and one for each half of the vertebral arch (Fig. 710). The halves of the neural arch unite posteriorly in the first year. This process of union, beginning in the cervical region at the end of the first year, progresses consecutively to the other regions and is completed in the sacrum toward the tenth year. The vertebral body is separated from the ventral part of the arch by a bar of cartilage (neurocentral synchondrosis) which disappears about the third or fourth year. Occasionally this may persist, particularly in the lumbar region, so that in interpreting roentgenograms of the vertebral column the anomaly may be mistaken for a fracture (see Spondylolisthesis, p. 759).

Five *secondary centers* appear at puberty, and the epiphyses they form add upper and lower plates, or disks, to the bodies and tips to the spinous and transverse processes. These epiphyses unite about the twentieth to the twenty-fifth year.

Faulty or arrested development of the primary centers may result in incomplete closure of the vertebral arch behind, with herniation of portions of the cord and membranes into the breach (*spina bifida*). Faulty or arrested development of the epiphysial plates of the secondary centers results in curvature, the *scoliosis of adolescence*. Developmental abnormalities may present in the transverse processes of the sixth and seventh cervical vertebrae and in the first lumbar vertebra in the form of cervical and lumbar ribs.

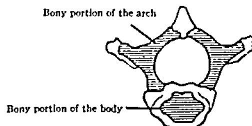


Fig. 710. PRIMARY CENTERS OF OSSIFICATION IN A TYPICAL VERTEBRA.

LANDMARKS. It is necessary in the study of pathologic conditions in the spine to differentiate and locate the vertebrae numerically (Figs. 706, 711). The cervical spinous processes are obscured by the thick, overlying ligamentum nuchae. From the tip of the seventh vertebra (*vertebra prominens*) to the inferior extremity of the spine the spinous processes are palpable. A line running through or joining their tips normally is median, so that a plumb line dropped from the prominent spinous process of the seventh cervical vertebra is in the line of the crease of the buttocks. Irregularities in this line of processes, whether lateral or anteroposterior, constitute the spinal deformities of scoliosis, kyphosis and lordosis, and call for a study of causes.

On each side of the line of spinous processes, which is represented on the strongly muscled subject as a groove, lies the longitudinally placed spinal musculature. In the thoracic region this musculature is limited laterally by the palpable line of the angles of the ribs. Forward bending shows the spinous processes in detail. Undue prominence of either line of rib angles indicates a structural spinal curvature with rotation of the vertebrae.

When the arms are at the sides, certain *transverse lines* joining recognized landmarks designate definite vertebrae and are aids in vertebral localization. Of these, the line joining the mesial extremities of the spines of the scapulae marks the spinous process of the third thoracic vertebra; that joining the inferior angles of the scapulae is in the line of the transverse process of the seventh thoracic vertebra; that at the level of the umbilicus usually locates the transverse process of the third lumbar vertebra. The level of the summits of the iliac crests crosses the spinous process of the fourth lumbar verte-

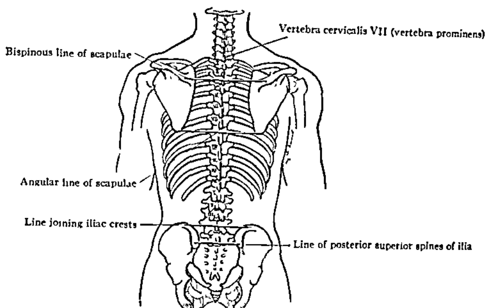


Fig. 711. LANDMARKS OF THE BACK.

bra; and the line joining the posterosuperior iliac spines marks the middle of the second sacral vertebra.

NORMAL CURVATURES OF THE SPINE. The vertebral column normally presents alternately placed anteroposterior curves (Fig. 706). The curves of the cervical and lumbar regions are convex anteriorly, and those of the thoracic and sacrococcygeal regions are concave anteriorly. The thoracic and sacrococcygeal curves suspend the thoracic and pelvic cavities and add greatly to their depth. The curves of the cervical and lumbar regions are compensatory. The lumbar curve forms a sloping shelf for the support of the heavy upper abdominal viscera. By directing the downward thrust of these organs forward against the lower abdominal musculature, the lumbar curve shields and protects the pelvic viscera. To its curves the spine owes much of its elasticity and its resistance to trauma acting in the line of the column. The curves are made possible by the *shape of the intervertebral disks. The disks of* the cervical and lumbar segments are thicker anteriorly, while those of the thoracic region are thicker posteriorly.

The normal curvatures vary according to age. In the newborn the vertebral column shows two *primary curves*, both concave forward. Of these, the upper extends from the head to the pelvis, and the lower affects the sacral region. As the child begins to sit erect and to elevate its head, *secondary curves* appear, the first of which is a forward convexity in the cervical region. As the child begins to stand and later to walk, a forward convexity appears in the lumbar region. The development of *these secondary curves enables the column* to transmit the weight of the trunk to the pelvis in such a way that little or no muscle effort is needed to maintain the erect attitude. As old age comes on, the spine tends to assume one great curvature with an anterior concavity. The cause of this is the atrophy of the intervertebral disks. The column then is shaped as it is when the individual vertebrae are articulated without disks. In females the lumbar curve is greater than in males, making a marked anterior prominence at its junction with the sacrum.

MOVEMENTS. The spinal column, although made up of superimposed vertebral bodies, firmly joined articular processes and reinforcing ligaments, is capable of a wonderful degree of flexibility (Fig. 712). It executes a great variety of movements, forward, lateral and backward bendings, rotation and even circumduction. *A large number of these movements is* made possible by the compressibility of the intervertebral fibrocartilages. The greatest degree and widest range of movement is in the segments which have the best-developed disks.

Not all segments of the spine permit the same variety of movement. In general, the greatest mobility occurs where one type of vertebra changes to another (cervicodorsal and dorsolumbar junctions). The vertebrae at these *levels are most liable to injury*. The cervical segment is very mobile and permits a wide

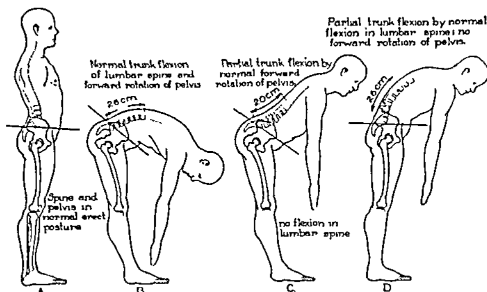


Fig. 712. FLEXION OF THE TRUNK IN STANDING POSITION.

The straight line between the anterior superior and the posterior superior iliac spines indicates the degree of flexion of the pelvis. In full lumbar spine flexion the distance between the eleventh thoracic and first sacral vertebrae is increased 6 cm. in the change of position from the erect posture to full lumbar flexion. (After Brahdy).

range of all movements. The thoracic region permits little movement in anterior and posterior flexion, thus adding to thoracic stability and preserving respiratory function. In the lumbar segment and through the lumbosacral articulation, anterior, posterior and lateral flexion is extensive (Fig. 713). In the sacroiliac synchondrosis there is only the slight mobility characteristic of such joints (e.g., sternoclavicular, symphysis pubis) which later in life become synarthroses.

These normal movements and curvatures are modified by inflammation, the deformities of paralysis, and fracture. In Pott's disease there is muscle spasm to maintain the spine rigid and to serve as a protective mechanism to lessen pain. A list of the trunk on the pelvic girdle may be assumed for relief of pain and tenderness in sacroiliac strain or in sciatica from whatever cause.

LUMBOSACRAL JOINT AND SPONDYLOLISTHESIS. Figure 713 indicates the tremendous shearing action exerted by the vertebral column on the *lumbosacral joint* and upon the interarticular areas of the lowermost lumbar vertebrae when the body is in the upright position. The potential force of weight-bearing exerted on these areas is increased almost unbelievably when activated by the inertia of motion, leverage, and muscle spasm resulting from sudden strains and falls. Increase in the

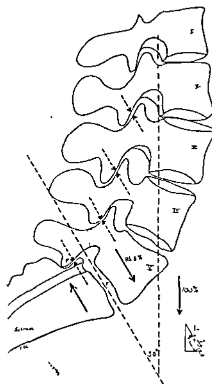


Fig. 713. DIAGRAM SHOWING THE FORCES ACTING ON THE INTERARTICULAR AREA (ISTHMUS) OF THE LAMINAE OF THE FIFTH LUMBAR VERTEBRA.

(From Chandler: Surg., Gynec. & Obst., 51: 273–306, 1931.)

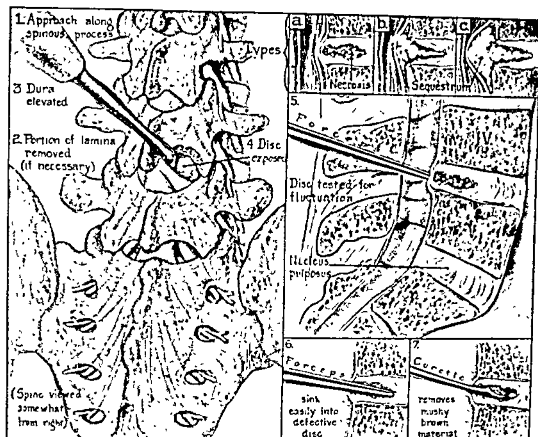


Fig. 714. RUPTURED INTERVERTEBRAL DISK. PATHOLOGY AND CORRECTION.

Left, Exposure of the ruptured disk, involving the following: approach along the spinous process (indicated at 1); removal of a portion of the dura mater (at 2), as is sometimes necessary; elevation of the dura mater (at 3); resultant exposure of the disk. *Upper right*, Three degrees of protrusion (*a*, *b* and *c*). *Middle right* (at 5), Method of testing for fluctuation, in which pressure upon the posterior longitudinal ligament causes an indentation because of the presence of softened tissue beneath. *Lower right*, Necrotic tissue, easily entered by instrument (at 6), is removed by curet (at 7). The mass of tissue, involving much of the interior of the intervertebral fibrocartilage, may be independent of the nucleus pulposus. (From Dandy: Ann. Surg., 115: 514–20, 1942. Published by J. B. Lippincott Company.)

normally sharp lumbosacral angle further lessens the security of the region.

Spondylolisthesis designates the slipping forward of a vertebral body. It occurs most commonly when the fifth lumbar vertebral body rides forward on the sacrum. The fourth lumbar body may slip forward on the fifth. The condition which usually allows a vertebral body to slip forward is a break in continuity in the interarticular area of one or both laminae. The term "isthmus" is applied to this region of the neural arch because it connotes a narrowing between two larger parts. The isthmus is at the point of maximum shearing force. Moreover, it often is the location for a congenital cleft or incomplete fissure. This marks out the interarticular area as one of defective ossification. Complete division of the isthmus with separation of fragments must be attributed to trauma. When rupture occurs through the isthmus, fibrous or cartilaginous tissue and not bone is severed. These separate and stretch under strain until the fifth lumbar vertebra, having lost its bony anchorage to the sacrum, slips forward to an amount allowed by the ligaments which unite the vertebral body to the sacrum, and those which unite the two portions of the defective arch. In a severe case the spinous process and attached laminae of the fifth lumbar vertebrae present dorsally as a single fragment, and are seen as a tumor at the lumbosacral junction.

An operation which produces bony fusion between the third and fourth lumbar vertebrae and the sacrum is the logical procedure to stabilize a spondylolisthetic spine.

The Intervertebral Disk (Fibrocartilage) and Its Protrusion. Between each two vertebrae there is a shock absorber in the form of the intervertebral disk. In the aggregate these disks form one fourth of the movable part of the spine. Each disk is attached inti-

mately to the compact rim of the superjacent and subjacent vertebral bodies, and is connected loosely to the limiting cartilaginous plates over their sievelike surfaces. It is composed of a dense mass of fibrocartilage (annulus fibrosus) surrounding the nucleus pulposus. The nucleus is a highly elastic, semifluid, indistensible tissue mass. The annulus fibrosus forms the larger part of the disk (Fig. 727). The nucleus pulposus lies rather more posteriorly than centrally. The annulus fibrosus gives form, size and strength to the disk, and constitutes its main weight-bearing portion.

When the spinal column is subjected to ordinary strain and stress, the disk bulges in all directions, but returns to its normal position after the force producing the stress has ceased to operate (Fig. 714). It is maintained in its position principally by the anterior and posterior longitudinal vertebral ligaments, the posterior ligament being the weaker of the two. After unusual strain to the column the disk itself, or its center, the nucleus pulposus, may be extruded beyond its normal limits and fail to return to position. Slight posterior protrusions may cause root pain because of pressure of the disk on one or more spinal nerve roots (Fig. 715). Greater protrusion may cause symptoms and signs similar to those in a transverse lesion of the cord or of the cauda equina. Thus the lesion may resemble an intraspinal neoplasm. The protrusion may occur at any level in the movable part of the column. The most common location is low in the lumbar region, and the most frequent symptom is sciatic pain. Protrusion of the disk through the cartilage plates of the superjacent and subjacent vertebral bodies and thence into their spongy interior occurs commonly.

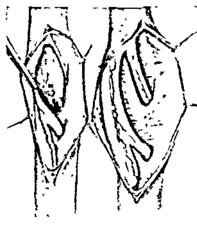




Fig. 715. TRANSDURAL EXPOSURE OF HERNIATED FIBROCARTILAGE.

Cartilage removed. (From Naffziger, Inman and Saunders: Surg., Gynec. & Obst., 66 288–99, 1938.)

Lesions which present objective neurologic findings are not difficult to diagnose. When there is motor weakness and sensory loss, the level of compression of the root or cord is determined by neurologic examination. The patient in whom pain is the only symptom presents a different diagnostic problem. The diagnosis then depends on fluoroscopic and roentgenographic examination of the spinal canal after injecting a radiopaque oil (Lipiodol) into the subarachnoid space. If protrusion of the disk is present, it will impinge on the column of Lipiodol and indent or displace it posteriorly or laterally because the protruded fragment of the disk is extradural. Complete obstruction to passage of the oil has been observed.

The therapy of choice for protruded disk is laminectomy with removal of the extruded part of the disk (Fig. 714), provided that the protruded disk corresponds to the level of the root pain.

HYPERTROPHY OF THE LIGAMENTUM FLAVUM. Hypertrophy of the ligamentum flavum is one of the more recently recognized intraspinal lesions which produce neurologic signs and symptoms by pressure on the cord, nerve roots or cauda equina.

The ligamenta flava, composed normally of yellow elastic tissue, connect the laminae of contiguous vertebrae and blend with the interspinous ligaments (Figs. 716, 717). They help form the capsules between the articular facets, and their lateral edge forms the posterior margin of the intervertebral foramina. In some patients one or more of these ligaments, probably from continued trauma, undergo hyperplastic change and become so thick that they encroach on the spinal canal and compress its contents. The ligament or ligaments usually thickened connect the laminae of the

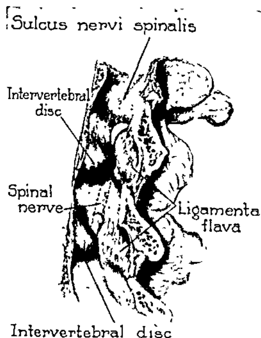


Fig. 716. RIGHT THIRD AND FOURTH LUMBAR INTERVERTEBRAL FORAMINA VIEWED WITHIN THE VERTEBRAL CANAL.

The apposition of the intervertebral disk and the ligamentum flavum may obliterate the inferior half of the bony foramen. The spinal nerve leaves through the upper half of the bony foramen. (From Naffziger, Inman and Saunders: Surg., Gynec. & Obst., 66: 288–99, 1938.)

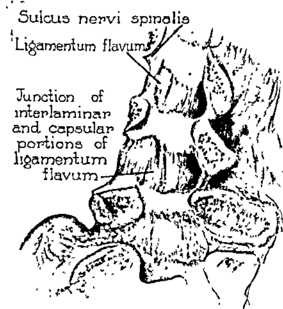


Fig. 717. SAGITTAL SECTION THROUGH LUMBAR AREA OF VERTEBRAL CANAL TO SHOW LIGAMENTA FLAVA.

(From Naffziger, Inman and Saunders: Surg., Gynec. & Obst., 66: 288–99, 1938.)

fourth and fifth lumbar vertebrae, so that the nerve elements compressed are the fibers of the cauda equina.

Low back pain, radiating down one or both thighs, motor weakness and objective sensory phenomena are the usual findings in an advanced case. There is usually a history of trauma. Fluoroscopic examination of the spinal canal after subarachnoid injection of a radiopaque oil (Lipiodol) locates the lesion (Fig. 718). The characteristic filling defect is at the fourth lumbar interspace.

Treatment consists in removal of the involved ligament or ligaments and the adjacent laminae. Spinal fusion may not be necessary. The tissue removed is a mass of dense fibrous material, different from the normally soft, pliable ligamentum flavum. Frequently the adjacent laminae are greatly thickened.

Surgical Considerations

ABNORMAL CURVATURES. Deviations from the normal curvatures of the vertebral column occur either in the anteroposterior or the lateral direction (Fig. 719). Deviations in the anteroposterior plane ordinarily are exaggerations of the normal curves.

The basic factors in these deviations range from faulty attitudes or postures to traumatic and disease processes. In sickly children and debilitated adolescents the body may grow too rapidly to be supported by its muscles. Instinctively, these patients adopt attitudes to relieve the overworked muscles and transfer the strain to the ligaments about the intervertebral joints. The ligaments upon which the strain is thrown are overstretched by habitual adoption of a compensatory attitude, and the opposing ligaments become shortened. Thus there is a tendency for the faulty attitude to be maintained. With improper alignment of the column the muscle balance is upset, and one group of muscles attains a mechanical advantage over the corresponding antagonistic group, to the end that the latter becomes overstretched.

KYPHOSIS, or increased backward curvature of the spine, commonly results from tuberculosis of the spine (Pott's disease) and occurs most often in the thoracic segment (Fig. 719, 1). The destruction of the vertebral bodies causes forward compression of the bodies and backward knuckling of the spinous processes.

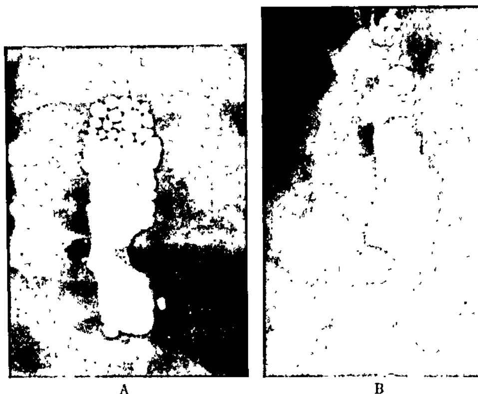


Fig. 718. DIAGNOSTIC SUBARACHNOID LIPIODOL INJECTION TO OUTLINE DISK PROTRUSION.

A, Postero-anterior view in prone position; *B*, prone oblique view. (H. A. Brown and J. W. Cox.)

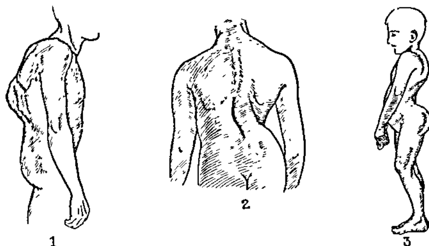


Fig. 719. COMMONER DEFORMITIES OF THE SPINE.

1, Thoracolumbar lordosis caused by Pott's disease; 2, left thoracolumbar scoliosis; 3, lordosis in double congenital dislocation of the hips.

The same deformity presents in compression fracture of the spine.

LORDOSIS, or exaggerated forward curvature in the lumbar segment, usually is compensatory to abnormal flexion or fixed flexion at the hip joint (Fig. 719, 3). It is exemplified in cases of double congenital dislocation of the hip in which the support of the pelvis is not through the acetabulum, but posterior to it. This increases the inclination of the pelvis and carries the lumbar spine into abnormal anterior convexity. Spondylolisthesis is another cause of lumbar lordosis.

SCOLIOSIS, or lateral curvature, is the commonest of the spinal deviations and occurs primarily in the thoracic region (Fig. 719, 2).

In the curve of scoliosis all or a series of the spinous processes show a constant deviation from the median line (Fig. 720). A careful study of the spine in its movements, checked by x-ray findings, is essential.

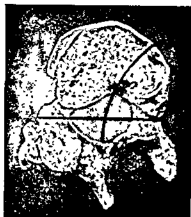


Fig. 720. DISTORTED SAGITTAL PLANE OF A SCOLIOTIC VERTEBRA.
(Riedinger.)

In *functional scoliosis* the convexity of the curve almost always is to the left. The spinous processes usually deviate about 1 cm., seldom more than 2.5 cm., from the median line. The left shoulder is carried high and forward, and the right shoulder downward and backward. Forward bending produces a prominence on the concave side of the curve. The prominence is the evidence of rotation of the vertebrae and is the result of bending the anteroposteriorly curved spine in more than one plane. It is produced by the rib angles. The curvature may be a sign of poor muscle tone or of faulty posture.

In *transitional scoliosis* the characteristics of functional scoliosis are observed except that a prominence presents at some level on the convex side of the curve. The usual prominence on the concave side of the curve is present at all other levels.

Structural scoliosis is a constant lateral deviation of the spine, characterized by changes in the vertebrae and in the surrounding muscles and ligaments. Forward bending produces a prominence on the convex side of the curve, because of the rotation of the vertebral bodies away from the point of greatest weight and pressure. If the curve is double, there are two prominences, each on the convex side of the curve. There are associated changes in the form and shape of the thorax, abdomen and pelvis.

ROUND BACK (STOOPED SHOULDERS) is an exaggeration of the convexity of the whole dorsal and even the lumbar segment. In some cases it is mechanical only; in others it may present bony changes. In old age a fixed round back is characteristic, because of the atrophy of the disks. In the HOLLOW BACK the lower part of the dorsal curve may be decreased or reversed, and the head be thrust forward. In FLAT BACK the physiologic curves of the dorsal and lumbar segments are lost.

TUBERCULOSIS OF THE SPINE. Tuberculosis of the spine, or Pott's disease, like tuberculosis in other bones and joints, is a local manifestation of blood-borne tuberculosis, characterized by bone destruction with but slight tendency to bone regeneration. It is accompanied by localized swelling, atrophy of tissues, and painful weight-bearing and movement. The spinal muscles maintain, as far as possible, a relieving or protective rigidity, and the pain caused by the return of muscle spasm following relaxation in sleep is responsible for night cries; these may be the initial sign of the disease. In the later stages there may be abscess formation with kyphos deformity and possible nerve root irritation, or even cord injury with paralysis of the lower extremities. Invasion by way of the upper and lower epiphysial plates is commonest in childhood. It occurs by extension from paravertebral abscesses, usually at the center of the anterior portion of the vertebral body. The process sometimes begins in the synovial cavity of an intervertebral disk. Rarely it begins in the transverse processes, spinous processes and in the posterior articulations.

The tuberculous process invades the vertebrae in a variety of ways. As the concavities of the physiologic curves carry the great stress of weight-bearing, disease of the bodies in the cervical or lumbar regions tends to less destruction than does disease in the thoracic region. Involvement in the thoracic bodies is formidable and is marked by serious deformity. Destruction of the intervertebral disks, especially in the thoracic curve, leads to collapse of the diseased tissues and results in the deformity of angular posterior projection of the spinous processes, the typical kyphos of Pott's disease. Thinning or destruction of the disk usually is the earliest roentgenographic finding.

The points of accumulation and paths of extension of pus from abscess formation in Pott's disease depend upon the spinal segment

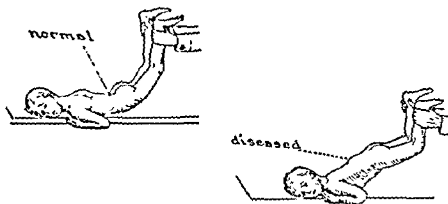


Fig. 721. METHOD OF DEMONSTRATING RIGIDITY OF THE SPINE IN VERTEBRAL TUBERCULOSIS. (From Babcock: Textbook of Surgery.)

involved. In the *cervical region* the abscess may bulge into the pharynx, obstructing respiration, and even rupturing into the mouth, suffocating the patient; it may accumulate in the deep tissues of the neck or, rarely, break into the spinal canal (Fig. 722). It commonly extends laterally into the floor of the supraclavicular area. Either the body or the odontoid process of the second cervical vertebra (axis) may be involved. From the odontoid process (dens) pus may extend forward and infect the joint between the dens and atlas, or backward and involve the bursa between the dens and the transverse ligament. When the dens is eroded or the transverse ligament is destroyed, the dens slips backward into the medulla, resulting in death, since cord injury occurs above the level of the origin of the phrenic nerve. These joints are supplied by branches from the first two cervical nerves which also supply the muscles rotating the head. Irritation of the joints sets up reflex phenomena in the cu-

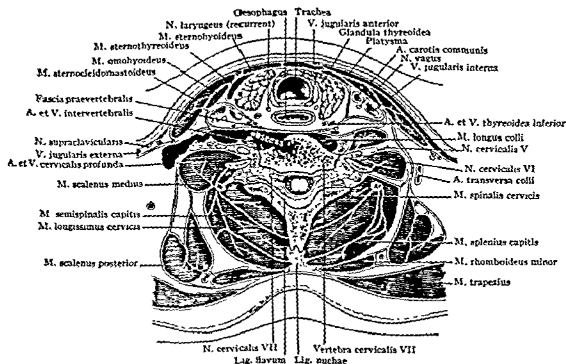


Fig. 722. CROSS SECTION THROUGH THE NECK AT THE LEVEL OF THE SEVENTH CERVICAL VERTEBRA TO SHOW TUBERCULOUS EROSION OF THE VERTEBRAL BODY AND LATERAL EXTENSION OF THE RESULTING TUBERCULOUS ABSCESS INTO THE SUPRACLAVICULAR REGION BEHIND THE PREVERTEBRAL FASCIA.

taneous and muscle distribution of the nerves, and the head is kept rigid from muscle spasm.

When the third or fourth cervical vertebra is involved, the same rigidity from muscle spasm is present, and there is pain over the distribution of the third and fourth cervical nerves. The symptoms are caused by pressure on the nerves themselves as they emerge from the vertebral canal, in contradistinction to the reflex symptoms noted in involvement of the joints between the articular processes.

When the *lower cervical* and *upper thoracic vertebrae* are affected, the corresponding part of the vertebral column is held rigid in muscle spasm, giving rise to the "military attitude" in walking, as well as to the typical habit of sitting with the elbows upon the table and supporting the chin to relieve the spastic muscles. The distribution of the referred pain may help to localize the exact site of the disease. When there is abscess formation, the pus tends to travel downward behind the anterior longitudinal ligament or prevertebral fascia into the mediastinum.

When the disease occurs in the *midthoracic segment*, muscle spasm occurs in the sacrospinalis muscle and sometimes in the abdominal muscles. Pain commonly is referred to the anterior abdominal wall, where it may lead to errors in diagnosis. Abscesses in connection with the involved vertebrae may gravitate downward behind the medial lumbocostal arch (internal arcuate ligament) and subsequently descend under the fascial covering of the psoas major muscle. Since modern treatment of these lesions usually is recumbency in hyperextension, these abscesses commonly gravitate upward. They form large paravertebral collections which may require evacuation by *costotransversectomy* (rib resection and removal of the corresponding transverse process) if they are infected secondarily or cause pressure symptoms on the spinal cord.

In involvement of the *lower thoracic* and *lumbar regions* pain may be present in the back, lower anterior abdominal wall, and the thigh or leg. The usual course of an abscess in these regions is along the psoas muscle on one or both sides to present in the groin, loin or buttock. There is associated spasm of the psoas muscle and resulting flexion of the thigh.

Spinal cord involvement by caries may occur in any portion of the vertebral column, but usually takes place in the dorsal spine. The paraplegia which may result usually is not caused by bony deformity, but by backward extension of the disease into the vertebral canal. Although the angular bony deformity may be so great as to cause actual compression, the condition arises so slowly that it may not lead to paralysis.

INJURIES OF THE SPINE. Injuries of the spine constitute a considerable number of industrial compensation cases. Difficulties are encountered not only in arriving at the correct interpretation of the results of the injury, the type and duration of treatment, the time of partial disability and the degree of permanent disability, but also the amount of compensation warranted. Injury to an already present deforming arthritis offers many serious difficulties in diagnosis and treatment. Many fractures are overlooked because of the relatively slight trauma necessary to produce them. Slight injuries to the column may cause serious results because of the delicate nature of the spinal cord and the nerve roots housed therein. The cord and its membranes may escape laceration and suffer concussion only, or any or all parts may be damaged, even to complete severance of the cord. The membranes may be torn, and hemorrhage may accumulate, causing pressure. Injuries to the cervical region are common because of the great freedom of movement permitted there.

Fracture is particularly common near the union of the flexible with the more fixed regions, and most frequently results from violent, exaggerated flexion. The trauma is spent on the large cancellous vertebral body, tending to produce compression fracture. Resistance is offered by the components of the neural arch, chiefly by the articular processes. If the posterior parts give way, subluxation may take place with less likelihood of compression fracture. Hyperextension is the proper treatment of compression fracture of the vertebral bodies.

A useful test for the diagnosis of fracture of the spine is the following (R. Soto-Hall): The patient is placed flat on his back without pillows. The examiner, with one hand, exerts gentle pressure upon the sternum so that no flexion can take place in the lumbar or thoracic regions of the spine. The examiner's other hand then is placed under the occiput and the head and neck are flexed upon the sternum slowly but forcibly. This movement pro-

duces a progressive pull upon the posterior spinous ligaments, starting at the ligamentum nuchae, and this pull is transmitted downward along the interspinous ligaments until it reaches the spinous process of the injured vertebra. The pull acts as a lever which gently compresses the injured vertebral body and which localizes pain accurately. The usefulness of this sign rests upon the ability to localize fractures without moving the patient and without examining the injured area locally.

Dislocation without fracture of the vertebrae is rare unless it occurs in the atlo-axoid junction, where the cord structures may escape damage because of the space afforded by the large vertebral canal, or between the fourth and fifth and between the fifth and sixth cervical vertebrae (Fig. 723).

Dislocation in the cervicodorsal region occurs most commonly where the flexible cervical segment meets the rigidly splinted thoracic segment. Unilateral dislocation of an articular process may come from a sudden twist or bend. The inferior articular process slips forward past the superior articular process of the vertebra next below and readily compresses the emerging spinal nerve, causing pain over its cutaneous distribution. The injury may bruise the cord directly or cause extravasation of blood into and around it with consequent sensory and motor changes, depending upon the extent and location of the lesion. Bilateral dislocations always are serious, and, if they destroy the spinal medulla in any of the four upper segments, death occurs from paralysis of the diaphragm and the accessory muscles of respiration.

Surgical Approach to the Cord (Laminectomy). It may be necessary, for a variety of reasons, to expose the spinal cord in the vertebral canal. Laminectomy is the procedure whereby the canal is opened widely to expose the dural sac, cord, and nerve roots. By this procedure, pressure from bony fragments, tumors or blood clots may be relieved; laceration in the cord membranes may be repaired or operations on the nerve roots or the cord be performed to relieve intractable pain.

The incision for laminectomy is made from the tip of the spinous process, superior to the one or two processes to be removed, to the tip of the next inferior process. The muscles are separated subperiosteally from the sides of the spinous processes and laminae, exposing the articular processes on either side. The bleeding at this step of the operation is controlled by packing tightly with gauze and retracting the muscle masses laterally. The interspinous and supraspinous ligaments are cut away. The spinous processes and then the laminae are removed with bone forceps, taking care not to injure the dura through the fat-filled extradural space. Just beneath the laminae and connecting them on their under surfaces is the tough ligamentum flavum, which is removed with the laminae. The subsequent procedure depends upon whether the tumor, blood clot, fracture fragment or foreign body is extradural or intradural. The dura is incised; since the arachnoid may be injured at the same time, subarachnoid fluid is likely to escape at once. When the operation has been completed, the cut edges of the dura are united carefully, and the thick muscle flaps are replaced.

Spinal Fusion Operations. Spinal fusion operations are designed to immobilize certain areas of the spinal column by an artificial ankylosis (arthrodesis). The indications for stabilizing operations on the spine are vertebral tuberculosis (Fig. 724), spinal injuries or deformities with persistent weakness and pain, and scolioses that tend to recur after correction has been obtained by traction and casts.

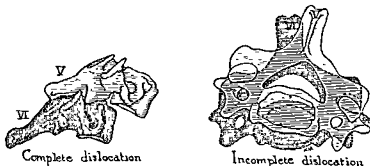


Fig. 723. COMPLETE AND INCOMPLETE DISLOCATIONS IN THE CERVICAL REGION.

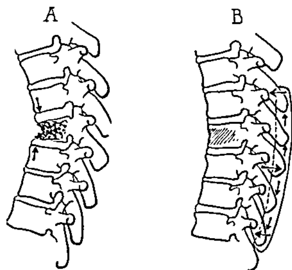


Fig. 724. INLAY GRAFT METHOD OF CORRECTING KYPHOTIC ANGULATION IN VERTEBRAL TUBERCULOSIS.

In *A* the arrows indicate the direction of the lines of the force which influence the crushing of the vertebral body; in *B* the arrows indicate the line of force directed to and from the graft inlay in the line of the spinous processes.

Hibbs' fusion is an osteoplastic operation for immobilizing the spinal column. It accomplishes arthrodesis of the intervertebral joints by destruction of the articular processes. It also builds bony bridges into the solid bone plates which embrace the vertebral arches of a succession of vertebrae, usually two above and two below the diseased vertebrae. The skin and subcutaneous tissue are incised from above downward, exposing the tips of the spinous processes of the vertebrae which are to be fused. Their periosteum and interspinous ligaments are split, and the dissection is carried down subperiosteally through that plane and is continued over the laminae to the articular and transverse processes, exposing the entire posterior aspect of the neural arches. Oozing of blood is controlled by gauze packs. The spinous processes are laid bare to their bases at the neural arch. The ligamenta flava are dissected from their attachments to the laminae and adjacent articular processes. The articulations of the pairs of articular processes are destroyed (arthrodesed). Bone flaps, hinged laterally, are raised from the adjacent laminae and applied as bridges across the spaces between the laminae. The spinous processes are nicked at their bases, allowing the processes to be broken down, so that their tips contact the raw places of the bases of the spinous processes below. Bony bridges are formed in this way, one in the midline and one on each side of the midline. In a variation of Hibbs' technique long osteoperiosteal strips may be removed from the tibia and placed along the laminae before closure of the soft parts. The components of the bony bridges are maintained in contact with denuded bone by suturing the overlying periosteum. The skin, subcutaneous tissue and muscle flaps are replaced and sutured.

The *Albee fusion* is an implantation of a bone graft along the channel of split spinous processes. The incision is carried through the skin and subcutaneous tissue, exposing the tips of the spinous processes. The supraspinous and interspinous ligaments are split in this line. With a wide chisel the processes are split into halves to a depth of 1 to 2 cm. The halves on each side are broken back and crowded laterally so as to present throughout a channel for the graft, which is taken from the crest of the tibia. The leg prepared for the taking of the graft is flexed on the thigh, incision is made over the tibial crest, and the anterior surface of the bone is exposed. The measurement for the graft is noted and marked on the exposed tibia. By means of a twin saw the graft is removed with the periosteum intact. This is placed in the channel made for it along the split spinous processes and is secured there by through-and-through chromic sutures.

MAJOR VESSEL DAMAGE IN LUMBAR DISK OPERATION. The operative removal of herniated nucleus pulposus is an established procedure in selected cases. A complication of this operation, probably occurring more often than is recorded in the literature, is accidental injury of the common iliac artery (Fig. 725). This complication might be anticipated, considering the close position of the anterior surface of the lumbar vertebrae to the major vessels at the aortic bifurcation area. Extension of instruments through the intervertebral space between the fourth and fifth lumbar vertebrae and the fifth lumbar and first sacral vertebrae is particularly hazardous.

NEEDLE BIOPSY OF VERTEBRAE FOR DIAGNOSIS OF BONE LESIONS. Despite the accuracy in the diagnosis of osseous lesions by combined clinical, laboratory and roentgenographic methods, there remains a large group of lesions, both neoplastic and inflammatory, in which the exact diagnosis can be determined only by histologic or bacteriologic examination

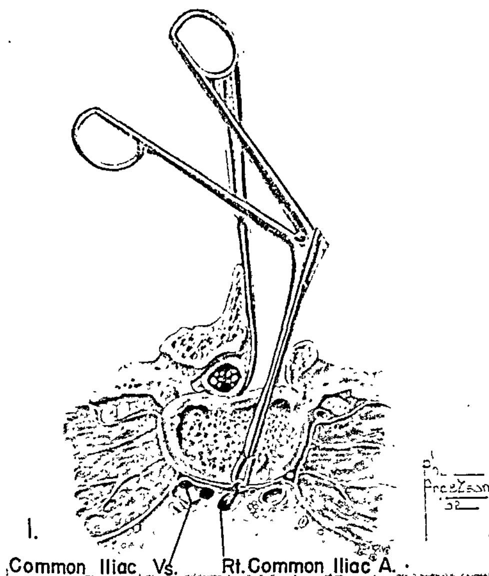


Fig. 725. MAJOR VESSEL DAMAGE IN LUMBAR DISK OPERATION.

Diagrammatic representation of the manner in which the common iliac artery was injured while using an angled pituitary rongeur at the fourth-fifth lumbar intervertebral space. (From Seeley, Hughes and Jahnke, Jr.: Surgery, 35: 421–9, 1954.)

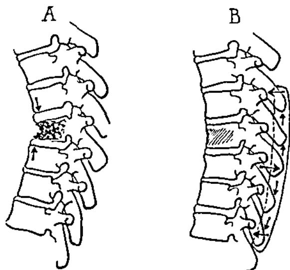


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CHAPTER 25

Vertebral or Spinal Canal

The collective vertebral foramina make a continuous central canal in the spinal column (Frontispiece, Part VII, Figs. 727 to 730). The anterior wall is closed uniformly by the posterior surfaces of the bodies of the vertebrae and their intervertebral disks, and the common posterior longitudinal ligament passes over it. The posterior and lateral walls are made up of the superimposed bony arches, the interspaces of which are spanned behind by the ligamenta flava and left open laterally as the intervertebral foramina. The whole is lined smoothly by periosteal and ligamentous surfaces. The well housed cord and its coverings and the spinal *nerve roots may be invaded by pathologic* processes through the intervertebral foramina or through the less protected interlaminar spaces, by extruded portions of an intervertebral disk, or by a thickened ligamentum flavum.

The form of the vertebral canal, although presenting some individual variations, is fairly constant (Figs. 708, 709). It is approximately circular where it is continuous with the foramen magnum, assumes a triangular form through the cervical region, becomes round through the thoracic region, and again assumes the triangular form in the lumbar region. Within the sacrum the canal flattens and expands laterally in the form of a crescent. In the flexible cervical and lumbar regions the canal has distinct enlargements to accommodate the cervical and lumbar enlargements of the cord.

SPINAL MENINGES, THEIR SPACES AND FLUID. The spinal meninges (Fig. 730) are the direct downward continuation of the cranial meninges (Figs. 728 to 730; *cf.* Figs. 13 to 15, pp. 11, 12). In the cranial cavity the *dura mater consists of two layers, the outer constituting* the lining periosteum of the skull, and the inner investing the brain and, by its duplications, forming the cranial venous sinuses (p. 13). At the foramen magnum the outer dural layer blends with the periosteal and ligamentous lining of the vertebral canal. The inner layer is tough and fibrous and forms the dural sac investing the more delicate meninges and

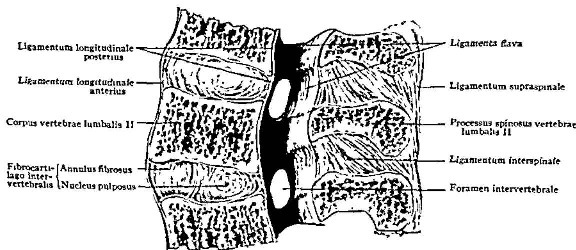


Fig. 727. SAGITTAL SECTION THROUGH THE SPINAL COLUMN IN THE LUMBAR REGION TO SHOW THE VERTEBRAL CANAL AND THE INTERVERTEBRAL FORAMINA.

Dolphin and Hammond* recently presented their technique (Fig. 726) and report that in sixty consecutive needle bone biopsy procedures fifty-four were analyzed, and fifty-two, or 87 per cent, were adequate for a pathologic diagnosis.

Their technique has been used in biopsies from the tenth dorsal through the fifth lumbar vertebra. As pointed out by others, needle biopsy of the upper nine dorsal vertebrae is not safe because of the proximity of the parietal pleura and the great vessels of the chest.

* S. Clin. North America, 37: 891–8, 1957.

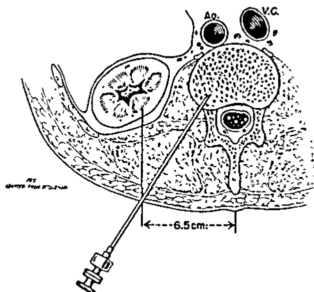


Fig. 726. ANATOMIC RELATIONS OF NEEDLE IN POSITION FOR BIOPSY OF LUMBAR VERTEBRAL BODY.

Biopsy of a lumbar vertebral body is performed with the patient lying prone and under light general anesthesia and roentgenographic control. A pillow is placed beneath the abdomen to elevate the spine and separate the transverse processes Preoperative posteroanterior roentgenograms of the lumbar spine are studied to note the relation of the transverse process to the spinous process of the diseased vertebra. The spinous process of the vertebra to be biopsied is usually located at the level of the transverse process of the next lower vertebra. A skin incision only large enough to admit the Turkel needle with a trephine tip is made 6 to 7 cm. to the right or left of the spinous process, depending upon the site of the major pathology. The outer needle and stylet are inserted at an angle of 45 degrees and directed inward and medialward until the transverse process of the vertebra below the "target" vertebra is struck, and the needle is then angled cephalad so that the tip glances off the superior surface of this transverse process. Further advancement in this direction will bring the tip of the needle in contact with the desired vertebral body.

Fluoroscopic examination will confirm the position of the needle, but roentgenograms in 2 planes should be made for verification. When the desired position of the needle has been confirmed, the outer needle and stylet are firmly imbedded in the bone. The stylet is then removed, and the trephine needle is inserted into the outer needle. When bone is encountered, the knurled extension handle is placed over the hub of the trephine needle, and successive turns of this needle are then made in one direction with sufficient downward pressure to advance it into the bony lesion. When the needle has reached sufficient depth, it is rotated several turns, without inward pressure, to cut off the core from its base. The trephine needle is then withdrawn with the specimen, which is expressed by means of the stylet. By slight change of the angle of the outer needle additional cores of tissue are removed. (From Dolphin and Hammond: S. Clin. North America, 37: 891–8, 1957.)

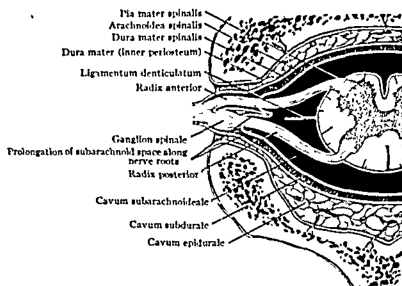


Fig. 730. SCHEMATIC TRANSVERSE SECTION THROUGH THE SPINAL CORD AND SPINAL MENINGES.

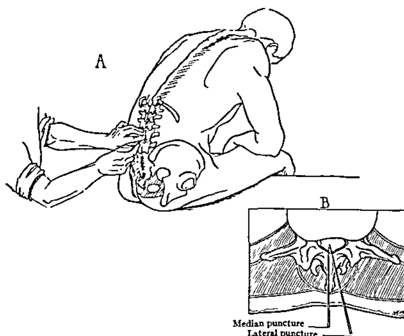


Fig. 731. TECHNIQUE OF LUMBAR PUNCTURE.

A, The left forefinger locates the area between the fourth and fifth lumbar spinous processes; *B*, a cross section at this level to show the median and lateral insertion of the needle into the subarachnoid space.

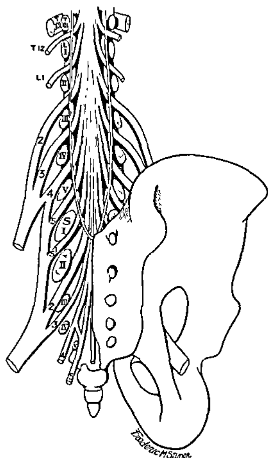


Fig. 728. RELATION OF THE NERVE ROOTS (TWELFTH THORACIC THROUGH FIFTH SACRAL) TO THE CAUDA EQUINA; SCHEMATIZED, TO EXPOSE THE *ROOTS WITHIN THE INTERVERTEBRAL AND POSTERIOR* SACRAL FORAMINA.

The pedicles of the vertebrae are indicated by Roman *numerals, the spinal nerves by Arabic. (From Haymaker and Woodhall: Peripheral Nerve Injuries.)*

cord and the emerging nerve roots. It also sends out expansions over the spinal nerves emerging through the intervertebral foramina (Fig. 730).

Between the dural sac and the walls of the vertebral canal is the *extradural space.* This is filled loosely with fatty areolar tissue and venous plexuses, and the whole is supported by connective tissue bands holding the dural envelope to the anterior and posterior walls of the vertebral canal. Spinal puncture may injure an extradural vein, and bloody cerebrospinal fluid may be withdrawn. Laminectomy without injury to the dural sac and cord is possible because of the extradural space, but is complicated if the extradural veins are injured, since only compression arrests the bleeding. The inflammatory products of vertebral tuberculosis may invade the extradural space and cause cord symptoms from pressure.

The spinal *arachnoid,* a delicate, nonvascular sac lining the dural tube and intimately connected with it, is the continuation of the cranial arachnoid. The dura and arachnoid move freely upon one another; the space between them is a potential cavity. The delicate arachnoid sac invests the cord loosely, and its deep space forms the outer limit of the subarachnoid space.

The *subarachnoid space* (Figs. 729, 730) is filled with cerebrospinal fluid, since it is in direct continuity with the subarachnoid cisterns surrounding the base of the brain and medulla. In lumbar puncture this space is entered when the needle penetrates the resistant dura and its subjacent thin arachnoid lining (Fig. 731).

The *pia mater* is a delicate vascular membrane closely attached to the fissures and surfaces of the cord and carrying blood vessels to its substance. It gives off numerous lateral septal prolongations to the arachnoid and adheres closely to the nerve roots, investing them with delicate sheaths which accompany the nerves across the subarachnoid space to

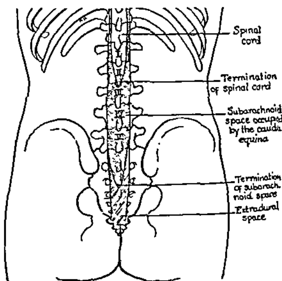


Fig. 729. DIAGRAM OF THE VERTEBRAL AND SACRAL CANALS TO SHOW THE LEVELS OF THE INFERIOR EXTREMITY OF THE SPINAL CORD PROPER AND THE LOWERMOST LIMIT OF THE SUBARACHNOID SPACE.

The diagram shows that spinal puncture in the lumbar area cannot injure the cord proper; the needle can meet only the fibers of the cauda equina. The diagram indicates also that the transsacral and caudal types of anesthesia are extradural in their location.

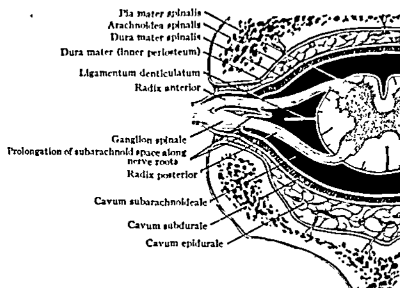


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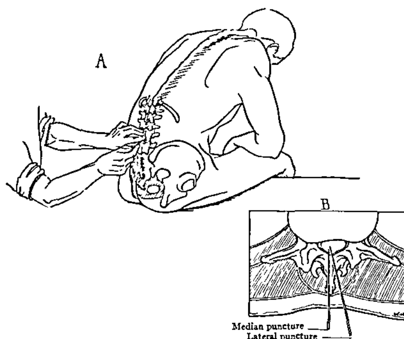


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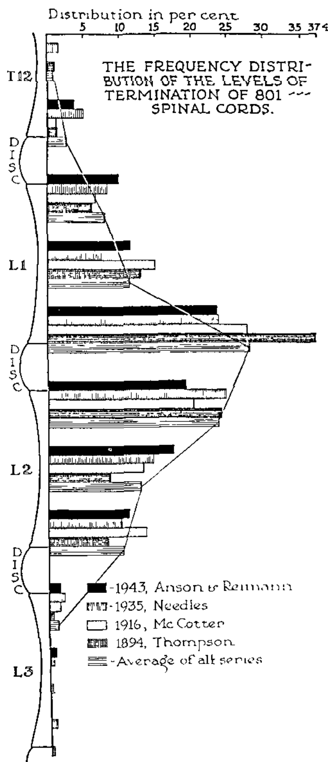


Fig. 732. GRAPHIC REPRESENTATION OF VARIATIONS IN THE VERTEBRAL LEVEL OF TERMINATION OF THE SPINAL CORD.

Records based upon 4 large series, and arranged in relation to thirds of a vertebra and a related intervertebral fibrocartilage; together these segments constitute 4 dimensional units. (From Reimann and Anson: Anat. Rec., 88: 127-38, 1944.)

blend with the dural sheath. The denticulate ligament is a frontally disposed sheet of membrane attached to the pia mater midway between the anterior and posterior nerve roots from the epistropheus (axis) to the first lumbar vertebra. Its lateral border is serrated; the serrations are attached to the dura in the intervals between the emerging nerve roots.

Surgical Considerations

Subarachnoid Anesthesia. Intraspinal or subarachnoid anesthesia is nerve root block produced by injection of a local anesthetic into the subarachnoid space. The anesthetic is administered by spinal puncture, performed with the patient in the sitting or in the lateral recumbent position. The fourth lumbar interspace is a favorite site for injection, since it is located readily on a line joining the crests of the ilia, and because the space is accessible by reason of the direct posterior projection of the lumbar spinous processes. At this level there is little likelihood of striking more than the fibers of the cauda equina, since the body of the spinal cord terminates at a higher level (Figs. 729, 732).

The interspinous space is located by palpation, and the needle is thrust through it in the median line. The resistant interspinous ligament is traversed, and the needle is inserted until it perforates the dense and somewhat elastic dura and the underlying arachnoid. Upon removal of the obturator, cerebrospinal fluid escapes. The injection of anesthetizing fluid is made slowly and with uniform pressure. Anesthesia produces almost complete loss of conduction of sensory and, to a less degree, of motor nerve impulses.

Sacral Anesthesia. Sacral anesthesia is extradural and is designed to reach the nerves within the sacral canal, where the anesthetizing solution saturates the sacral nerves and produces anesthesia in the parts supplied by them (Figs. 733, 734). When 30 cc. of the solution are injected, the extradural space is invaded as far as the lower lumbar region (Farr). Anesthesia is afforded the structures of the perineum and the external genitals.

In the *caudal type* of sacral anesthesia the patient is placed in the prone position, the sacral hiatus is located, and the overlying structures are anesthetized. Puncture is made into the sacral hiatus through the resistant

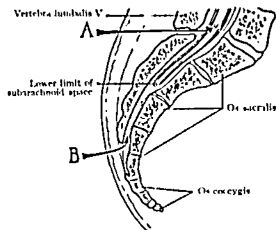


Fig. 733. MEDIAN SAGITTAL SECTION THROUGH THE FIFTH LUMBAR VERTEBRA AND THE SACRUM TO INDICATE AREAS FOR SUBARACHNOID AND EXTRADURAL INJECTIONS.

A shows the point of injection into the subarachnoid space through the superior aperture of the sacral canal. *B* indicates the point of injection for caudal extradural anesthesia.

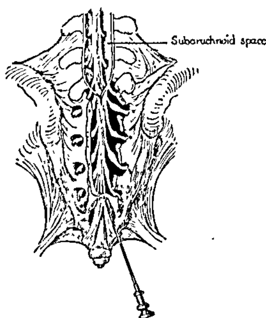


Fig. 734. SACRAL NERVES EXPOSED IN THE SACRAL CANAL. THE CAUDAL TYPE OF SACRAL EXTRADURAL ANESTHESIA IS INDICATED.

The needle penetrates the posterior sacrococcygeal ligament to enter the inferior aperture of the sacral canal.

sacrococcygeal ligament with a fine long needle, the hub of which is depressed until the shaft passes upward along the axis of the sacral canal for a distance of 3 or 4 cm. Fifty cubic centimeters of a 2 per cent solution of procaine are deposited in the canal, where they bathe the emerging sacral and coccygeal nerves. The needle point, if improperly directed, fails to enter the canal, but travels upward posterior to the sacrum.

Transsacral (posterior sacral) anesthesia is accomplished by direct injection of an anesthetizing fluid into the sacral canal and about the sacral nerves by way of each of the posterior sacral foramina (Fig. 735). The first sacral foramen lies about 3 cm. lateral to the line of sacral spinous processes, and the foramina of each side are from 2 to 2.5 cm. apart. As practical landmarks, the posterosuperior spines of the ilia should be located. About 1 cm. mesial to, and just below, these spines lie the second sacral foramina. Usually, infiltration of only the lower four pairs of sacral nerves is made. The first pair of sacral foramina is located on a line directly opposite the tip of the transverse

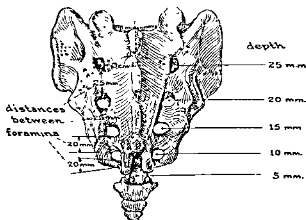


Fig. 735. POSTERIOR VIEW OF THE SACRUM AND THE POSTERIOR SACRAL FORAMINA.

The diagram indicates the depth of the foramina from the surface and the distances between the foramina. These measurements are aids in the injection of sacral anesthesia by the transsacral route. (From Babcock: Textbook of Surgery.)

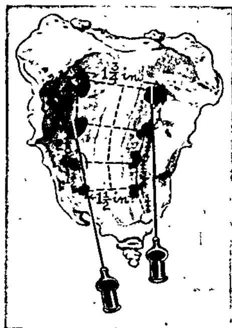


Fig. 736. POSITIONS OF THE NEEDLES USED IN THE INJECTION OF PRESACRAL ANESTHESIA.

The needles are shifted to conform to the shape of the sacrum as they pass from the sacrococcygeal junction to the higher sacral vertebra. The distances between the foramina are indicated. (From Bickham: Operative Surgery.)

process of the fifth lumbar vertebra. Because of the greater thickness and forward inclination of the sacrum above, it is necessary to introduce the upper needles a greater distance than the lower. The efficiency of this method may be augmented by caudal injection of the sacral canal.

For the administration of *presacral anesthesia* the patient is placed in the exaggerated lithotomy position, in which the sacral plexus can be reached anterior to the sacrum alternately at the right and left of the sacrococcygeal joint. The points of entrance are about 1.5 to 2 cm. from the median line (Fig. 736). On each side the needle travels upward and laterally along the anterior surface of the sacrum, the nerves being anesthetized by the infiltration block method. As the needle encounters the anterior surface of the sacrum, the anesthetizing fluid is allowed to escape rapidly in advance of the needle until a large amount of the fluid is deposited in the hollow of the sacrum. The fluid forces the rectum forward out of danger.

PARAVERTEBRAL ANESTHESIA. In paravertebral anesthesia an effort is made to anesthetize the spinal nerves a short distance from their emergence from the column. The special field for this anesthesia lies in the abdominal and thoracic regions. The needle may be introduced from 2 to 3 cm. lateral to the midline until the vertebral arch is touched. It then is passed 1 cm. deeper between the transverse processes, where it encounters the nerves as they emerge from the intervertebral foramina. Although anesthesia may be obtained in this manner, it is almost impossible to reach all the emerging nerves. For infiltration block the needle may be introduced obliquely inward somewhat farther from the median line, from 3 to 4 cm. lateral to the point between the transverse processes.

CHAPTER 26

Spinal Cord and Nerve Roots

The spinal cord, or medulla spinalis, when freed from its coverings and attached nerves, presents the general form of an elongated cylinder, compressed anteroposteriorly. The foramen magnum defines the level at which the cord is continuous with the medulla oblongata. The relations of the cord and vertebral column differ greatly in the fetus, infant and adult. Up to the third month of intrauterine life the cord occupies the entire length of the vertebral canal. After the third intrauterine month the column lengthens more rapidly than the cord, so that the cord appears to shrink upward in the vertebral canal. At birth the lower end of the cord is opposite the body of the third lumbar vertebra. In the adult the lower level of the cord usually lies opposite the lower level of the first or the upper level of the second lumbar vertebra (Figs. 728, 729, 732). From the inferior limit of the spinal cord (conus medullaris) a glistening thread, the terminal filament, is prolonged downward within the vertebral canal; it anchors the medulla to the coccyx.

Gray Matter of the Cord. Cross section of the cord shows the gray matter on either side of the midline arranged in a comma-shaped mass with well defined columns which project anteriorly and posteriorly lateral to the connecting gray commissure (Fig. 737). The *anterior column*, short, broad, and blunt at its extremity, contains the motor cells which give origin to the fibers of the anterior nerve roots. The *posterior column* is pointed, and near its tip the posterior nerve roots enter the spinal cord. The cord levels with the largest amount of gray matter are the cervical and lumbar enlargements, whence emerge the great nerve

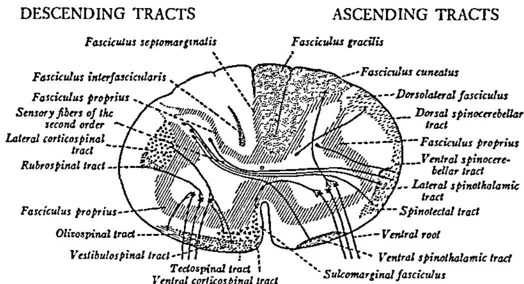


Fig. 737. DIAGRAM SHOWING THE LOCATION OF THE PRINCIPAL FIBER TRACTS IN THE SPINAL CORD OF MAN. ASCENDING TRACTS ON THE RIGHT SIDE, DESCENDING TRACTS ON THE LEFT.

The fibers of the corticospinal tract that supply the cervical segments of the cord lie in its medial portion; those supplying lumbar segments lie laterally with fibers to thoracic segments between. (Walker, 1940.)

trunks forming the large limb plexuses. In the thoracic region the amount of gray matter is reduced, corresponding with the smaller size of the thoracic nerves.

WHITE MATTER OF THE CORD. The white matter of the cord is seen on cross-section as the field between the gray column and the cord periphery. The milky-white color is that of the medullary substance about the transversely cut nerve fibers. These fibers, although indistinguishable anatomically, differ functionally, part being motor and part sensory.

The POSTERIOR (DORSAL) AREA of white matter is divided by the posterior median septum into a right and left column or funiculus. Each of these funiculi is divided by a paramedian septum into a mesial tract, the *fasciculus gracilis* (of Goll), and a lateral tract, the *fasciculus cuneatus* (of Burdach). The sensory fibers of which these tracts are composed enter the gray matter by the posterior nerve roots and are the centrally directed axons of nerve cells which lie in the spinal ganglia. The majority of these fibers pursue an uncrossed upward course along the mesial side of the posterior column of gray matter. Most of the impulses conducted in these fasciculi are transformed into impressions of muscle and joint sensation. Destruction of the nerve cells in the spinal ganglia, which give rise to these long ascending fibers, causes degeneration of the fibers and prevents the muscle and joint sensations essential for equilibrium from reaching the brain centers; ataxic movements result. This destruction is the essential and constant lesion of tabes dorsalis.

The remaining mass of white matter is designated roughly as the ANTEROLATERAL COLUMN, most of which consists of nerve fibers springing from nerve cells in the gray column. These fibers form an intrinsic system which links different levels of the spinal cord.

The more important systems of fibers are the lateral cerebrospinal (crossed motor or pyramidal) tract, the anterior cerebrospinal (uncrossed motor or direct pyramidal) tract, the dorsal and ventral spinocerebellar tracts, and the spinothalamic and spinotectal tracts.

The *lateral cerebrospinal* (*crossed motor* or *pyramidal*) *tract* is the great motor connection bringing the spinal motor apparatus under control of the brain. It lies anterior and lateral to the posterior column of gray matter, and its fibers arise from the pyramidal cells in the motor area of the cerebral hemisphere. Most of the fibers cross the median plane (decussate) in the medulla. Destruction of these fibers as they descend in the brain substance causes paralysis in the muscles supplied by the motor nerves in the opposite side of the cord. In each spinal segment which the fiber bundle traverses, numerous fibers enter the anterior column of gray matter and ramify about the motor cells from which the fibers of the corresponding anterior nerve root are derived.

The *anterior cerebrospinal* (*uncrossed motor* or *direct pyramidal*) *tract* is a small motor nerve strand lying near the anterior median sulcus of the cord. It arises in the motor area of the cortex and continues down the cord on the same side. While the bundle as a whole does not decussate as it enters the cord from the brain, the fibers at each point along the downward course cross to the opposite side and ramify about the motor cells in the opposite gray matter.

The *dorsal spinocerebellar fasciculus* (of Flechsig) and the *ventral spinocerebellar fasciculus* (of Gower) convey sensations from the muscles and overlying skin which aid muscle coordination between the cord and the cerebellar centers of coordination. *Spinothalamic* and *spinotectal* tracts carry sensations of pain and temperature.

SPINAL NERVE ROOTS, GANGLIA AND NERVES. An anterior and a posterior nerve root attach each spinal nerve to the cord. The *anterior* (*ventral*) *nerve roots*, which are purely motor, emerge in series from the anterior column of gray matter. The *posterior* (*dorsal*) *nerve roots*, which are purely sensory, enter the spinal cord in series on its posterolateral aspect. On each posterior root is a *ganglion*, the cells of which give origin to central and peripheral fibers. The ganglia of all, save the sacral and coccygeal nerves, occupy the intervertebral foramina. Those of the sacral and coccygeal nerves lie within the vertebral canal. Within or near the intervertebral foramen each pair of nerve roots unites to form a *spinal nerve*, which almost at its formation divides into an anterior and a posterior branch or primary division (Fig. 738). Both divisions are mixed (sensory and motor) nerves. Just distal to the division, the spinal nerve gives off a minute recurrent branch to the meninges and cord after uniting with a branch from the sympathetic trunk (Figs. 738, 739).

Each nerve root receives an investment from the pia mater and another from the arachnoid just before the root meets the dura (Fig. 730). Within the subarachnoid space the roots are bathed in cerebrospinal fluid. Outside the space, the nerves are encased in a tubular sheathing of dura which includes the ganglion on the posterior root.

Path of Sensory Conduction. The path of sensory conduction is more complicated than that of motor conduction. It is composed of at least three sets of neurons disposed one above the other. The cells of the *lowest set* of *sensory neurons* lie in the ganglia of the posterior nerve roots. The axon of a ganglion cell divides in such a manner that one portion runs to the spinal cord and the other to the periphery of the body. The peripherally disposed sensory fibers make up the peripheral sensory nerves and conduct sensory impulses toward the ganglion cells from various specialized end-organs. The centrally disposed fibers enter the cord by the posterior roots and are the true axons of the nerve cells. They conduct sensory stimuli to the cord. The axons terminate in the cord in a variety of ways: many terminate about the cell bodies of the lower motor neurons to complete the reflex pathway; others divide into ascending and descending branches which travel in the white matter. Some of the ascending branches run upward to the medulla to end about cells in the cuneate and gracilis nuclei of the dorsal columns. Other fibers (pain and temperature), after traveling two to three segments up the cord, cross to the opposite side and ascend in anterolateral tracts.

The cells lying in the nuclei of the dorsal column with their centrally directed axons form the *middle sensory neurons*. These axons, after decussating, do not run to the sensory cortex directly, but end in cells in the thalamus.

The cutaneous fields corresponding to the peripheral sensory nerve distribution are well known. The site and outline of the segmental cutaneous fields represented by the dorsal roots are known less accurately, but aid in determining the level of cord and dorsal root lesions.

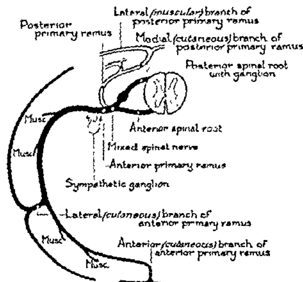


Fig. 738. COMPONENTS OF A TYPICAL SPINAL (SEGMENTAL) NERVE.

Nerve roots, anterior primary ramus and the latter's branches are shown in black; the posterior ramus and its derivatives are indicated in outlines. *Musc.* refers to muscular branches originating from the anterior primary ramus. (From Haymaker and Woodhall: *Peripheral Nerve Injuries.*)

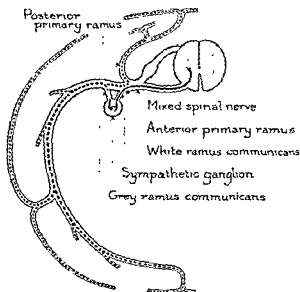


Fig. 739. COURSE OF SYMPATHETIC FIBERS WITHIN A TYPICAL SPINAL NERVE.

Preganglionic fibers are indicated by a solid line, postganglionic fibers by broken line. (From Haymaker and Woodhall: Peripheral Nerve Injuries.)

Surgical Considerations

Diagnosis of Lesions in the Motor Pathway. Abnormality of motion usually is the most important localizing sign of lesions in the motor pathway. The impairment of function varies according to whether an upper or a lower motor neuron is involved.

Degeneration which follows a destructive lesion in the *lower* (*spinomuscular*) *motor neuron*

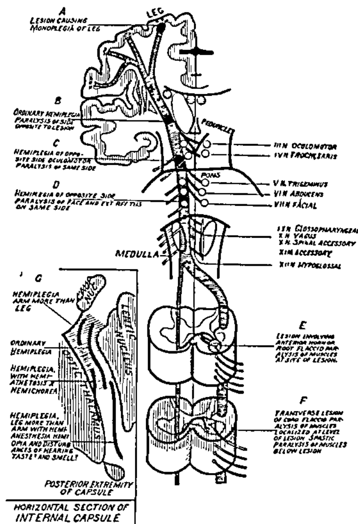


Fig. 740. EFFECT OF LESIONS (INDICATED BY CIRCLES) IN THE MOTOR PATH OF THE BRAIN AND THE SPINAL CORD.

G, Internal capsule lesions and the variations in symptoms caused by the different anteroposterior locations of the lesions. (Butler.)

involves the axis cylinders which run in the peripheral nerves. The muscles in which they end are weakened or paralyzed (Fig. 740). With an irritative lesion the muscles supplied by the nerve involved are thrown into abnormal contractions. The muscles of a paralyzed limb become small and flabby, the limb hangs helplessly, and the joints are relaxed because the articular processes no longer are held in close apposition by tonic contracture of the muscles about them. The muscle reflexes and tonus which depend upon the integrity of the reflex arc, of which the lower motor neuron is the efferent limb, are lost.

A lesion in the lower motor neuron causes paralysis of a few muscles only or, at the most, of a group of muscles. Sensory symptoms which may accompany the paralysis assist in making an accurate diagnosis (Figs. 741 to 745). If paralysis with characteristic signs of a lower motor neuron lesion involves a group of muscles supplied by one nerve, and the anesthetic area of skin belongs to that nerve, the lesion obviously is in the nerve itself. If the paralyzed muscles are not supplied by a single nerve, but are represented together in the cord, and the anesthetic area corresponds to that segment or segments, it is clear that the lesion must be in the cord itself or in a nerve root.

The *upper* (*corticospinal*) *motor neurons* are wedged into a small space, and a small lesion may cause paralysis of many muscles. The compact motor fiber bundle, the pyramidal tract, may have enough fibers involved in the internal capsule to produce paralysis of most of the muscles of the opposite side of the body (hemiplegia). The tract descends as a compact bundle, most of the fibers of which decussate

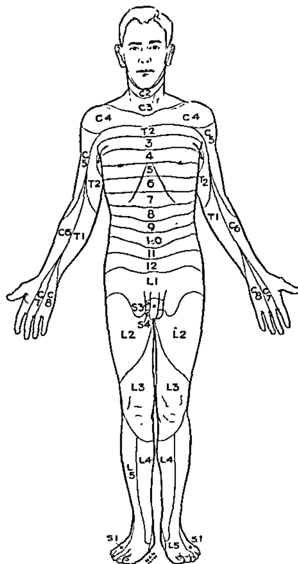


Fig. 741. SEGMENTAL INNERVATION OF THE SKIN FROM THE ANTERIOR ASPECT.

The uppermost dermatome adjoins the cutaneous field of the mandibular division of the trigeminal nerve. The arrows indicate the lateral extensions of dermatome T 3. (Modified from Foerster, in Haymaker and Woodhall: Peripheral Nerve Injuries.)

in the medulla. The pyramidal tract gives off fibers to the motor nuclei at successive levels. A lesion anywhere in its course results in paralysis of all the muscles the spinal centers of which lie below the level of the lesion. Above the internal capsule the fibers are separated somewhat, so that in the cerebral cortex the centers controlling different sections of the body are comparatively far apart. A sharply localized cortical lesion causes a limited paralysis in a limb or a segment of a limb (cerebral monoplegia).

Destructive lesions in the upper (corticospinal) motor neuron cause paralyses with distinctive characteristics. The paralysis is accompanied by a spastic condition, exaggerated muscle reflexes and increased muscle tension. All the muscles of a limb are involved about equally. The limb is stiff and can be moved only slowly and with difficulty because of muscle rigidity. The muscles are hypersensitive to irritation, so that tapping a muscle tendon elicits a quick muscle response. The muscles atrophy somewhat.

In complete transverse section of the cord the paralyzed muscles are flaccid and their reflexes absent.

DIAGNOSIS OF LESIONS IN THE SENSORY PATHWAY. Destruction of the sensory pathway in any part of the body deprives that part of

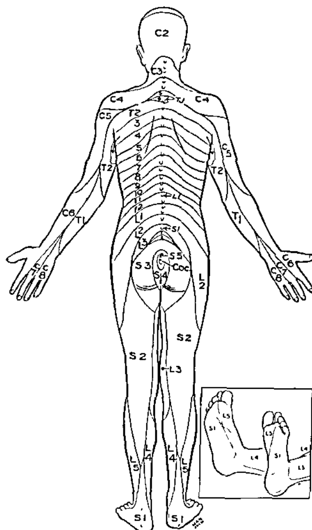


Fig. 742. DERMATOMES, IN POSTERIOR VIEW.

Cutaneous innervation by the first cervical segment is wanting. Arrows in the axillary regions indicate the lateral extent of dermatome T 3; those in the region of the vertebral column point to the first thoracic, the first lumbar and the first sacral spinous processes. (After Foerster in Haymaker and Woodhall. Peripheral Nerve Injuries.)

all qualities of sensation. Sensory loss occurs most frequently from a lesion of the sensory neurons in the peripheral nerves; the anesthetic area depends upon the nerve involved. Unilateral lesions in the cord or in the higher sensory centers cause disturbances in sensation on the opposite side of the body. As a rule, destructive lesions do not involve all the paths of sensory conduction, and the loss of sensibility usually is not complete. Astonishingly slight disturbances may be consequent upon fairly extensive lesions. Pain and temperature sensation may be lost and touch sensation remain normal, or muscle sense may be lost and the stereognostic sense (ability to recognize an object by the sense of touch) remain unimpaired. The distribution rather than the character of sensory loss is of consequence, and even distribution may give but insecure localization of the lesion. A combination of paralysis and sensory changes affords the most secure diagnosis.

VERTEBROMEDULLARY AND RADICULAR TOPOGRAPHY. Careful determination of the height at which a vertebral body or a cord segment is injured is a point of primary importance in the diagnosis and surgical treatment of cord and vertebral body disease (Fig. 746). There can be no direct operative approach until a proper segmental diagnosis pointing to the site for laminectomy has been made.

The cord reaches inferiorly only to the level of the second lumbar vertebra, so that each of the cord segments is smaller than the corresponding vertebral body, and its nerve roots cannot leave the column at the same height as

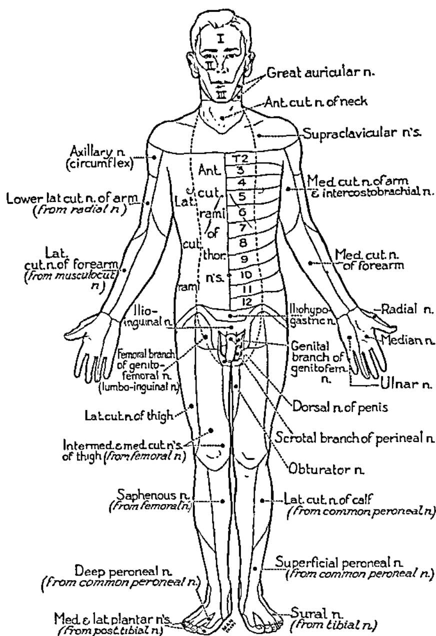


Fig. 743. FIELDS OF CUTANEOUS SUPPLY BY PERIPHERAL NERVES; SEEN FROM THE ANTERIOR ASPECT.

Numbers on the left side of the trunk refer to the intercostal nerves. On the right side are shown the cutaneous fields of the lateral and medial branches of the anterior primary rami. The asterisk just beneath the scrotum is in the field of the posterior cutaneous nerve of the thigh. (From Haymaker and Woodhall: Peripheral Nerve Injuries.)

Fig. 744. FIELDS OF CUTANEOUS INNERVATION BY PERIPHERAL NERVES; FROM THE ANTEROLATERAL ASPECT.

The face and anterior half of the head are innervated by the 3 divisions of the trigeminal: I, ophthalmic; II, maxillary; III, mandibular. The fields of the intercostal nerves are indicated by numerals. The unlabeled cutaneous field between great and second toe is supplied by the deep peroneal nerve. (From Haymaker and Woodhall: Peripheral Nerve Injuries)

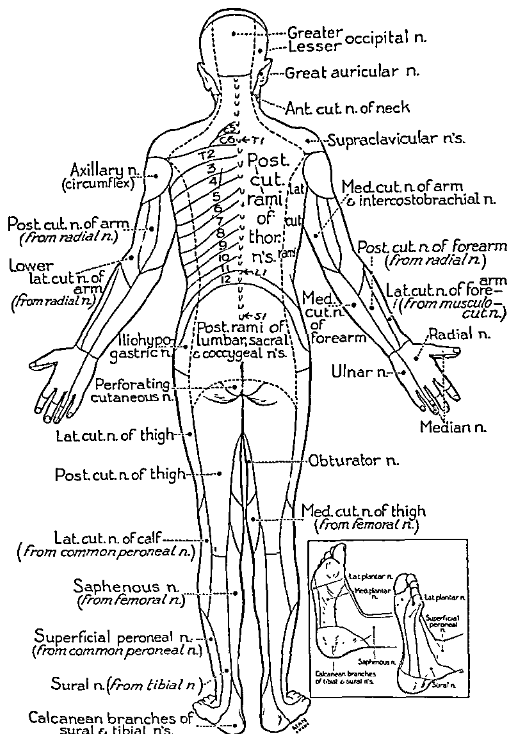


Fig. 745. FIELDS OF CUTANEOUS INNERVATION BY PERIPHERAL NERVES; POSTERIOR VIEW.

The boundaries of cutaneous supply of the posterior primary rami are indicated by broken lines. The designation, *Post. cut. rami of thor. n's.*, refers to the cutaneous branches of the posterior primary rami; *Lat. cut. rami* indicates the distribution from the lateral branches of the anterior primary rami. For purposes of orientation the spinous processes of the first thoracic (T 1), the first lumbar (L 1) and the first sacral (S 1) vertebrae are indicated by arrows. (From Haymaker and Woodhall: Peripheral Nerve Injuries.)

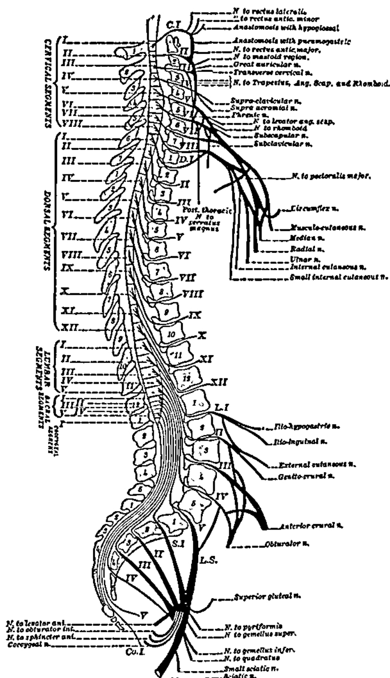


Fig. 746. RELATIONS OF THE SEGMENTS OF THE SPINAL CORD AND THEIR NERVE ROOTS TO THE BODIES AND SPINOUS PROCESSES OF THE VERTEBRAE.

(Déjerine and Thomas, modified by Starr.)

they leave the cord. The nerve roots run an appreciable distance downward within the vertebral canal before reaching the intervertebral foramina through which they pass. Because of discrepancy between the length of the spinal cord and that of the vertebral column, the farther down the cord, the greater the distance between the attachment of the individual nerve roots to the cord and their emergence through the intervertebral foramina (Fig. 746).

In order to determine the vertebral level at which a spinal cord lesion occurs, the exact difference in the levels of vertebral and cord segments must be known. The discrepancy in level between the numerically corresponding cord segments and vertebrae is measured roughly in vertebral bodies. It becomes pro-

gressively greater from above downward. In the cervical and upper thoracic regions the cord segments lie one or two vertebral bodies higher than the numerically corresponding vertebrae; that is, cord segment C 7 lies at the level of vertebral body C 5. In the lower thoracic and upper lumbar regions the cord segments lie two or three vertebral bodies higher; cord segment T 12 is at the level of vertebral body T 10. In the lower lumbar and upper sacral regions cord segments lie four or five vertebral bodies higher; cord segment L 5 is at the level of vertebral body T 12 or L 1.

CORD INJURIES. Early examination and careful observation of cord injuries are essential to proper treatment. A partial lesion gradually becoming more extensive is evidence of advancing change in the cord which should be investigated by laminectomy and exploration of the vertebral canal. Signs of a complete cord lesion which appear at the moment of injury usually indicate complete destruction of the cord. Complete cord lesions rarely are improved by operation. Occasionally, however, removal of a bony fragment pressing on the cord is followed by improvement.

Spinal puncture and the Queckenstedt test are helpful in determining the method of treatment. The *Queckenstedt test* utilizes manometric readings of cerebrospinal fluid pressure. The contents of the cranium are packed so economically within the skull that any increase in intracranial volume raises intracranial pressure, an increase which is transmitted to the cerebrospinal fluid system. Compression of both internal jugular veins above the sternal ends of the clavicles dams back blood in the skull and thus raises intracranial pressure. When a tumor completely obstructs the spinal canal and, therefore, the flow of the cerebrospinal fluid, that part of the subarachnoid space superior to the tumor is cut off from that part below it. An increase in pressure in the fluid system above the tumor will not be transmitted to that part of the system below the tumor.

To perform this test, a lumbar puncture is made in the low lumbar region, and the needle is connected to a manometer. The jugular veins are then compressed. If there is no increase in pressure in the fluid in the manometer, there is a block in the subarachnoid space somewhere between the needle and the skull. Thus, immediately after injury, pressure may show free communication between the cranial and lower spinal fluid spaces. A few hours later, manometric readings may indicate a complete block. These findings indicate increasing pressure on the spinal cord and call for laminectomy as a means of exploring and decompressing the cord.

A *complete transverse lesion of the cord* is followed by total sensory and motor loss in the regions innervated by the cord segments below the lesion. This is characterized by a flaccid paralysis and an abolition of all reflexes below the level of the injury. Voluntary control of the bladder and rectum is lost, but sometimes these organs regain an automatic power of evacuation. This is especially true if the cord lesion is above the third and fourth sacral segments, where the centers for the bladder and rectum are located. If the cord lesion occurs in these segments, complete bladder and rectal retention is more likely to occur.

A complete cord lesion at the level of the fourth cervical segment (second cervical vertebra) usually is fatal because paralysis of the phrenic nerve at its origin in the fourth cervical segment results in paralysis of the diaphragm. Frequently, lesions even one or two segments below the fourth cervical segment involve the phrenic nerve because of edema of the cord above the injury.

Lesions involving the cauda equina usually show patchy nerve involvement below the level of injury, with partial paralysis and sensory impairment. The sphincter power may or may not be lost, depending upon the completeness of the injury.

Partial injuries of the cord manifest spastic paralyses of varying degrees below the level of injury. Sensation is decreased, but not abolished, reflexes are increased, the great toe reflex is positive, and there may be complete loss of sphincter control.

Hemisection of the cord results in complete paralysis of the muscles innervated by the segments below the lesion, on the same side of the body as the lesion. There also are sensory changes, the location of which depends upon the sensory tracts involved. Those fibers which carry pain and temperature sensations cross the median line immediately on entering the cord. Therefore hemisection interrupts pain and temperature sensations only on the side opposite the lesion. The fibers carrying pressure sensation and tactile discrimination pass

upward in the cord without crossing, so that hemisection interrupts pressure sensation and tactile discrimination only on the side of the lesion. Posture and movement sensations, however, are lost only in the paralyzed limb, since they are carried in fibers which ascend on the same side until they reach the medulla, where they decussate. A narrow zone of anesthesia is present at the upper limit of the motor paralysis where the sensory fibers are involved as they enter the cord. The position of the anesthetic strip is a certain indication of the site of the lesion.

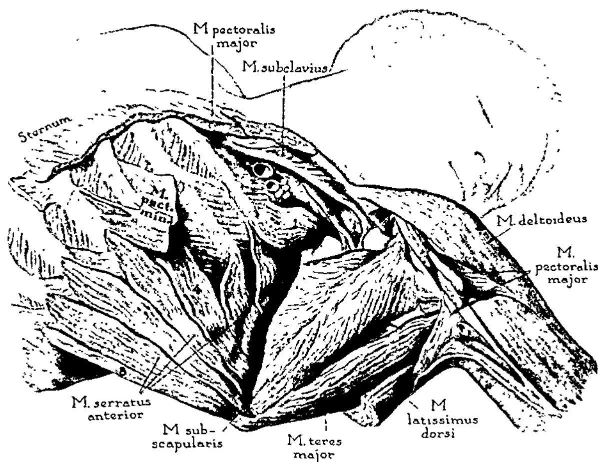
RHIZOTOMY AND CORDOTOMY. If intractable pain cannot be relieved by ordinary measures, section of the sensory nerve roots, rhizotomy, or section of the pain tracts in the cord, cordotomy, may be resorted to.

Rhizotomy is the operation of preference in the neck, because cordotomy may injure fiber tracts to the brachial plexus and phrenic nerve. *Cordotomy*, or section of the anterolateral columns in the spinal cord, is effective in the relief of pain on the side opposite the incision. For relief of pain below the costal margins, cordotomy is more effectual than rhizotomy. Exposure for either operation is gained through a laminectomy at a point well above the foraminal entrance of the involved spinal nerves. In cordotomy, traction is made on the denticulate ligament lateral to the cord in such a manner that the cord is rotated dorsally and laterally. A knife is then inserted straight into the cord, just ventral to the denticulate ligament, to a depth of 3 mm. An incision made ventrally and laterally from this point should interrupt the pain and temperature tracts and cause anesthesia on the side opposite the incision. Section may be unilateral or bilateral.

Great care must be taken to avoid injury to the pyramidal tract fibers in order to prevent paralysis and loss of sphincter control. It is advisable to perform the operation under local anesthesia, so that sensory tests may be made to indicate the amount of anesthesia obtained. The results in either procedure are variable, and the anesthesia produced may not effect abolition of pain.

PART VIII

The Upper Extremity



MUSCULAR BOUNDARIES OF THE AXILLA

CHAPTER 27

Shoulder

The shoulder is differentiated topographically into four divisions: the axillary, posterior scapular, and deltoid regions, and the bones and joints.

Axillary Region

The axilla is the space situated between the upper lateral aspect of the chest wall and the proximal part of the upper limb. It is shaped like a pyramid with a blunted apex. The apex or inlet of the space transmits the large vessels and nerves which pass between the upper limb and the root of the neck. With the arm at rest along the thorax, the muscle walls of the region are relaxed, and the examining hand can palpate the full extent of the fossa and examine the head of the humerus and the thoracic walls as far as the second rib. When the arm is in right-angle abduction, the fossa becomes a groove with the anterior and posterior walls in apposition. In exaggerated abduction the axillary fossa is obliterated, and its structures are made tense.

WALLS OF THE AXILLA. The axilla presents for examination an anterior or clavipectoral wall, a posterior or scapular wall, a mesial or costal wall, and a lateral or humeral wall (Frontispiece, Part VIII; Figs. 747 to 749).

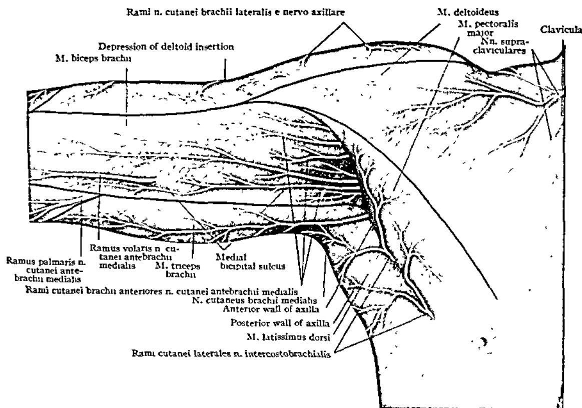


Fig. 747. SURFACE ANATOMY AND THE AREAS OF CUTANEOUS NERVE DISTRIBUTION IN THE AXILLARY REGION.

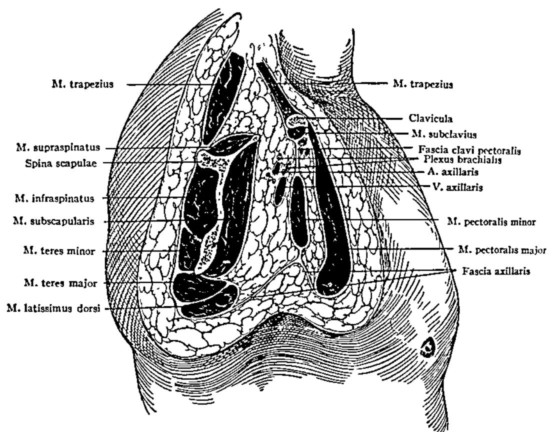


Fig. 748. SAGITTAL SECTION THROUGH THE AXILLARY FOSSA TO SHOW THE CONTENTS AND THE MUSCULAR AND FASCIAL WALLS.

The ANTERIOR WALL consists of two main strata. The pectoralis major muscle with its enveloping fascia forms the outer stratum, and the pectoralis minor muscle with the costo-coracoid membrane of the clavipectoral fascia forms the deeper stratum (Figs. 748, 749). When the superficial structures have been removed, the *pectoral fascia* is seen to enclose the pectoralis major muscle. This fascia attaches above to the clavicle and mesially to the sternum. It closes the superficial deltopectoral (infraclavicular) triangle laterally and is continuous below with the fascial covering of the serratus anterior and external oblique muscles. It blends with the axillary fascia in the floor of the axilla and with the fascia of the arm. Because the fascia contains many efferent mammary lymphatics, its removal is necessary in carcinoma of the breast (p. 275).

Division and reflection of the pectoralis major muscle in the anterior wall of the axilla expose the *coracoclavicular* (*clavipectoral*) *fascia*, which extends from the clavicle above to the axillary fascia below. The incision for evacuation of an abscess under the coraco-clavicular fascia is the same as that made for infraclavicular ligation of the first portion of the axillary artery.

After enveloping the pectoralis minor muscle the clavipectoral fascia descends to meet the axillary fascia in its stretch from the anterior to the posterior axillary folds. Between the two strata of the anterior wall of the axilla is a celluло-areolar interval, the interpectoral compartment, in which vessels and nerves to the pectoral muscles ramify, and in which an interpectoral abscess sometimes is formed.

The MEDIAL (COSTAL) WALL of the space corresponds to the five upper ribs and their intervening spaces which are concealed by the upper digitations of the serratus anterior muscle (Frontispiece, Part VIII; Fig. 750). The serratus anterior arises from the lateral surfaces of the upper eight ribs, a short distance in front of the midaxillary line. Its fibers pass backward, closely applied to the chest wall, and are inserted into the ventral aspect of the vertebral border of the scapula. The serratus anterior pulls the scapula forward and, when opposed by the rhomboid muscle, steadies the scapula in the movement of forward pushing. By acting with the trapezius muscle to rotate the scapula,

it enables the arm to be raised above the head. The long thoracic nerve (of Bell) (C 5, 6, 7) appears from behind the axillary vessels and enters the serratus anterior muscle on its superficial aspect.

The LATERAL WALL of the axilla, to which the important axillary vessels and nerves are related, is formed by the coracobrachialis and biceps brachii muscles, the proximal part of the shaft of the humerus, and the mesial aspect of the shoulder joint (Frontispiece, Part VIII; Fig. 750).

The POSTERIOR (SCAPULAR) WALL is composed of the subscapularis muscle on the anterior surface of the scapula, and the latissimus dorsi (p. 409) and teres major muscles (Fig. 750). The subscapularis arises from the subscapular fossa (Frontispiece, Part VIII) and converges toward the head of the humerus, where it is inserted by a thick tendon into the lesser tubercle of the humerus and into the capsule of the shoulder joint. The posterior wall of the axilla approaches the anterior wall closely at the level of the intertubercular sulcus of the humerus; the angular interval separating the two is occupied by the long and short heads of the biceps and the coracobrachialis muscles. The axillary vessels and nerves lie in close relationship with the medial aspect of these muscles.

The structures constituting the FLOOR of the axilla are the skin, subcutaneous tissue and axillary fascia (Fig. 748). The axillary fascia is an ill-defined, resistant membrane. Because of its great strength, deep abscesses rarely perforate it.

The APEX of the axilla is in communication with the supraclavicular fossa along the axillary vessels and nerves and the surrounding areologlandular tissue (Fig. 750).

AXILLARY VESSELS AND NERVES. The axillary sheath is a downward and lateral prolongation of the prevertebral fascia from the neck. It encloses the axillary vessels and nerves (Figs. 749, 750), as well as a few apical lymph nodes, and is lost upon the neurovascular elements as they pass outward from the axilla. In axillary

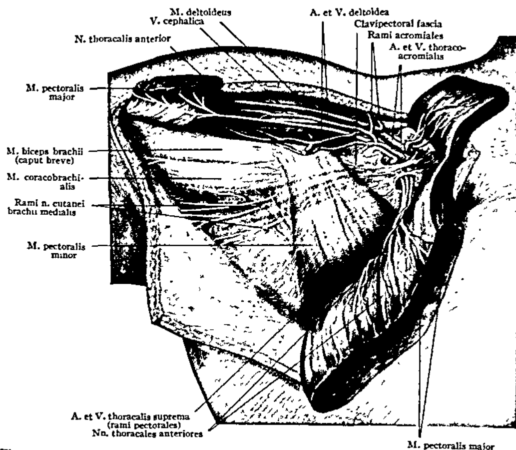


Fig. 749. FRONT VIEW OF THE AXILLARY REGION WITH THE PECTORALIS MAJOR PORTION OF THE ANTERIOR WALL OF THE AXILLA REMOVED.

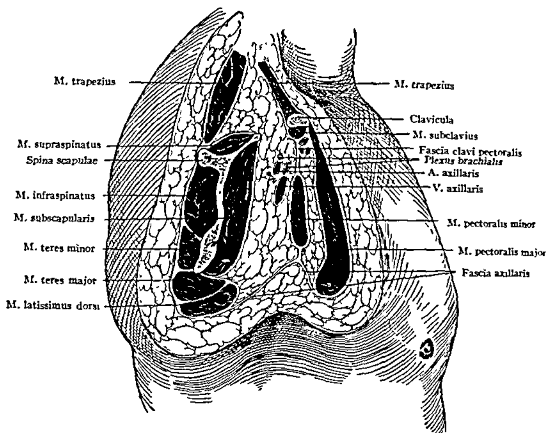


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the third division of the axillary is the largest branch.

The axillary artery is related to the capsule of the shoulder joint and therefore is exposed to pressure from anterior dislocation of the head of the humerus, especially if the dislocation is extreme and the head is mesial to the coracoid process. The artery may be injured in delayed reduction of shoulder dislocations. Where the artery lies over the subscapularis tendon and the fusion of the tendon with the capsule of the shoulder joint, it is exposed to lacerations from fracture of the surgical neck of the humerus and from epiphysial separation.

The AXILLARY VEIN is formed from the union of the basilic and the two brachial veins (Fig. 750). Its principal affluent is the cephalic vein, which enters it a short distance below the clavicle through the crease between the pectoralis major and deltoid muscles (deltopectoral, infraclavicular triangle). The subscapular tributaries of the axillary vein have a wide anastomosis with the veins of the thoracic wall; since these tributaries are associated with the axillary lymph nodes, they must be removed along with the nodes as a routine measure in radical removal of the breast for carcinoma. With the arm in abduction, the vein lies anterior to the artery, hiding it from view. The intimate relations of the artery to the vein explain the frequency of traumatic arteriovenous aneurysm. A wound in the upper part of the axillary vein is particularly dangerous, not only because of profuse hemorrhage, but also because of the risk of air entering the vessel, the walls of which tend to be held apart by the fibrous expansions thrown over the vessel by the coracoclavicular (clavipectoral) fascia. It is advisable in all axillary operations to clear the axillary vein as soon as possible to avoid wounding it in the course of subsequent dissection.

It is important to be able to identify the various NERVES of the brachial plexus as they surround the third division of the axillary artery (Fig. 750). The *median nerve* is recognized by its great size and its two heads of origin. Because of its superficial position, it is the nerve most frequently involved in wounds of the axilla. The *musculocutaneous nerve* is smaller than the median and occupies a lateral position where it reaches and pierces the coracobrachialis muscle. The *ulnar nerve* may be difficult to distinguish from the *medial* (*internal*) *cutaneous nerve* of the forearm, since both arise from the median cord and are overlaid by the axillary vein at their origin. The ulnar is the larger and more posterior. The *radial* (*musculospiral*) *nerve* is the direct continuation of the posterior cord and differs from the ulnar nerve by its posterior position and greater size. In the axilla the radial nerve is exposed to pressure in improper use of a crutch. From the posterior cord arises the *axillary* (*circumflex*) *nerve*, which runs a posterolateral course upon the neck of the humerus. It may be lacerated or contused by dislocation of the head of the humerus or by fracture fragments. Injury of this nerve (p. 918) causes atrophy of the deltoid muscle, loss of the rotundity of the shoulder, and an area of cutaneous anesthesia over the deltoid.

AXILLARY LYMPH NODES. The axillary lymph nodes are embedded in the areolo-adipose tissue occupying the axillary space. They are arranged in several groups. The *anterior* or *pectoral* (*thoracic*) *group* lies in the mesial part of the axilla, against the serratus anterior muscle and between the posterior surface of the pectoralis major muscle and the coracoclavicular (clavipectoral) fascia. An abscess arising from these nodes tends to point at the upper or lower margin of the pectoralis major muscle. This group drains not only the outer part of the breast, but also the superficial layers of the anterior abdominal wall above the umbilicus, and the side of the chest. The *lateral* (*brachial*) *group* accompanies the axillary vein on the lateral wall of the axilla, receives the lymphatics from the upper limb, and is the *first group of axillary glands to be involved in* lymphangitis of the hand and forearm.

The *posterior* (*subscapular*) *glands* are arranged about the posterior axillary fold upon the subscapularis muscle and are associated with the subscapular vessels and the thoracodorsal nerve. They drain the superficial layers of the back of the chest and some of the anterior pectoral glands. The *apical nodes* lie high up in the axilla behind the coracoclavicular fascia. They drain the pectoral, subscapular and lateral groups of glands and are connected with the infraclavicular nodes in the superficial deltopectoral (infraclavicular) triangle. In carcinoma the apical glands may become adherent to the axillary vein, thereby necessitating excision of a part of that vessel. The glands sometimes obstruct the cephalic vein as it pierces

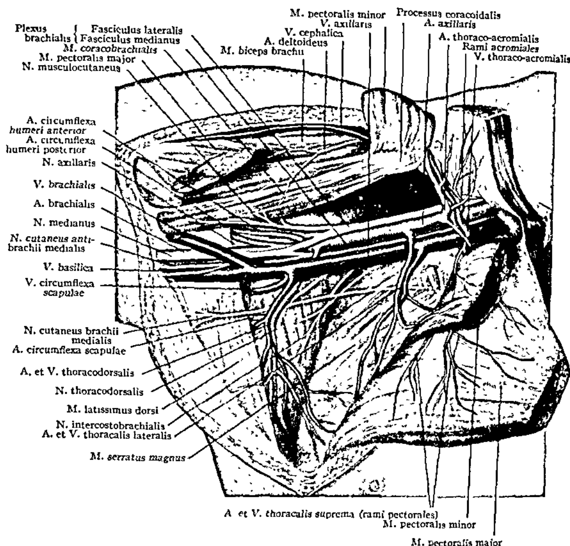


Fig. 750. VASCULONEURAL CONTENTS OF THE AXILLA AFTER REMOVAL OF THE ANTERIOR OR PECTORAL WALL OF THE AXILLARY FOSSA.

dissection for carcinoma of the breast the apical nodes are removed by excising part of the sheath.

The AXILLARY ARTERY is the direct continuation of the subclavian artery; it extends from the outer margin of the first rib to the lower border of the teres major muscle, beyond which it is known as the brachial artery (p. 827). Throughout its course it is accompanied closely by the axillary vein and has intimate, although changing, relations with the nerves of the brachial plexus. The artery is divided into three stages corresponding to the parts of the vessel situated proximal, behind and inferior to the pectoralis minor muscle (Fig. 749).

The *first division* of the artery lies behind the clavipectoral fascia and the clavicular head of the pectoralis major muscle.

The *second division* of the artery, that behind the pectoralis minor muscle, is the shortest. About it are arranged the medial, lateral and *posterior cords of the brachial plexus*, exactly as their names indicate.

The *third division* of the artery at first is overlaid by the pectoralis major muscle, but becomes superficial before reaching its termination. The *terminal nerves of the brachial* plexus are arranged about it, two on each side. Laterally lie the musculocutaneous nerve and the lateral head of the median nerve; anteriorly are the medial head of the median nerve and the medial cutaneous *(internal)* nerve of the forearm; mesially, between the axillary artery and the axillary vein, is the ulnar nerve; and posteriorly lie the radial (musculospiral) and axillary (circumflex) nerves. The axillary nerve leaves the artery at the lower border of the subscapularis muscle and passes backward through the quadrilateral (external axillary) space (Fig. 731). The subscapular artery from

when the subclavian artery is ligated in its third division.

The third division of the axillary artery is superficial and is the site of election for ligation. The incision for *ligation of the artery in the third division* is made through the outer part of the armpit parallel to the course of the vessel. After the superficial tissues have been divided the coracobrachialis muscle is exposed and drawn outward with the musculocutaneous nerve. The axillary artery lies in the depth of the wound, surrounded by the large brachial nerves. Probably the best site to apply the ligature is between the origin of the subscapular artery and the two circumflex arteries, but the vessel may be tied immediately proximal to the origin of the subscapular artery. In the latter instance the collateral circulation is carried on by the anastomosis between the intercostal, lateral thoracic, transverse cervical, transverse scapular (suprascapular) and thoraco-acromial arteries proximal to the ligature, and by the subscapular and humeral circumflex arteries on the distal side of the ligature. When the axillary artery is tied between the subscapular and circumflex branches, anastomosis between the humeral circumflex arteries and the branches of the thoraco-acromial and transverse scapular arteries reestablishes the circulation. When the subscapular and humeral circumflex vessels arise by a common trunk, and a ligature is applied distal to the vessel, the collateral anastomosis follows the same course as in ligation of the brachial artery proximal to the origin of the profunda artery.

Posterior or Scapular Region

The scapula with its embracing musculature occupies the posterior part of the shoulder (Fig. 751) and affords valuable protection to that part of the chest wall to which it is applied. It serves to connect the humerus with the trunk and to increase greatly the range of movements of the upper extremity, so that, even with a firmly ankylosed shoulder joint, considerable mobility is retained. The infrequency of fracture of the body of the scapula results mainly from the protective action of the many muscles which clothe it.

LANDMARKS. The posterior aspect of the scapula is divided by the scapular spine into an upper or supraspinous and a lower or infraspinous area. The *scapular spine* extends upward and laterally from the vertebral margin of the bone opposite the third thoracic spinous process to become continuous with the *acromion*. The spine, acromion, *vertebral border*, and *inferior angle* of the scapula are palpated easily, especially when the shoulder is retracted with the elbow drawn out from the side. In wasting diseases these bony landmarks become prominent.

An important action of the serratus anterior muscle is maintenance of the scapula in close contact with the chest wall. As a sequel of paralysis of the serratus anterior muscle from injury to the long thoracic nerve (of Bell) in operations in the axilla or from a blow or undue pressure upon the shoulder, the vertebral border and inferior angle of the scapula lose contact with the chest wall and project from it like a wing (*winged scapula*). This deformity is rendered more striking by pressing forward against a wall with the arms extended at shoulder level.

SUPERFICIAL STRUCTURES. The skin over the scapula is thick and is bound down closely to a dense subcutaneous tissue. Over the intrinsic scapular musculature pass the trapezius, deltoid and latissimus dorsi muscles. These are intrinsic in adjoining regions and, with their enveloping aponeuroses, form a powerful musculofibrous layer.

POSTERIOR SCAPULAR MUSCLES. The *supraspinatus muscle* (N. suprascapular, C 4, 5, 6) arises from the supraspinous fossa and the deep surface of the dense, overlying aponeurosis (Figs. 751, 752). It runs outward under the acromion into the deltoid region, where it inserts on the uppermost of the three facets on the greater tuberosity of the humerus and blends with the capsule of the shoulder joint. When the arm is in abduction, the supraspinatus rotates it slightly outward; its primary function is to initiate lateral elevation of the arm.

The infraspinatus, teres major and teres minor muscles lie in and about the infraspinous fossa under the dense infraspinous aponeurosis, which blends laterally with the overlapping deltoid sheath. The *infraspinatus muscle* (N. suprascapular, C 4, 5, 6) arises from the infraspinous fossa and runs upward and laterally to insert into the middle facet on the greater tuberosity of the humerus. It is a lateral rotator of the arm. The *teres minor muscle* (N. axillary, C 5, 6, 7) arises just below the infra-

the coracoclavicular fascia. Efferents from this group of glands open into the lymph channels at the root of the neck.

Surgical Considerations

AXILLARY ABSCESSES. Axillary abscesses occur in the pectoral region or in the axillary space. A *pectoral* or *interpectoral abscess* from involvement of the anterior pectoral glands cannot extend upward into the neck, since it is confined between two layers of fascia, both of which are attached to the clavicle. As a rule, the abscess is not large, and becomes superficial either in the infraclavicular fossa or at the level of the anterior axillary fold.

An *abscess within the axillary space* usually is of lymphatic origin, the causative infection draining from a neighboring source, particularly from the fingers. It may occur from infection within the shoulder joint or in one of the upper ribs. A common source is infection spreading down an axillary hair follicle. If the suppurative process is not checked, the whole axilla may be converted into an abscess cavity. In the presence of abscess the normally concave floor of the axilla bulges convexly downward. Because of the free communication between the apex of the axilla and the supraclavicular fossa, the abscess readily extends upward behind the clavicle into the root of the neck. Its backward progress is checked by the attachment of the serratus anterior muscle to the scapula. Extension of the abscess into the arm along the great vessels occasionally is observed.

The proper *treatment* of axillary abscesses is early evacuation of their contents and the establishment of free drainage. The incision should be directed between and parallel to the anterior and posterior axillary folds to avoid injury to the lateral thoracic and subscapular vessels. An abscess from infection of the apical group of lymph nodes lies behind the coracoclavicular fascia, and the incision for drainage is the same as that for infraclavicular ligation of the first portion of the axillary artery.

AXILLARY ANEURYSM AND INJURY TO THE AXILLARY ARTERY. The comparative frequency of *axillary aneurysm* may result from the free range of mobility of the artery and its close proximity to the heart. The presence of an aneurysm usually is revealed by a fluctuant swelling in the axilla. If the upper divisions of the artery are implicated, the tumor tends to project forward below the clavicle through the infraclavicular fossa. When the aneurysm springs from the third stage of the vessel, the anterior axillary fold is raised, the hollow of the armpit disappears, and a soft, pulsating mass presents. Because of the laxity of the tissue about the artery, the aneurysm meets with little resistance, and its growth usually is rapid. Pressure of the aneurysm on the nerves of the brachial plexus causes pain and, subsequently, a loss of cutaneous sensibility in certain areas of the upper limb. Loss of power in the upper extremity may result from interference with the motor nerves, and edema of the arm and hand from compression of the axillary vein.

Injury of the axillary artery sometimes occurs in the reduction of old dislocations at the shoulder joint while breaking down adhesions between the axillary vessels and the tissue about the dislocated head of the humerus.

LIGATION OF THE AXILLARY ARTERY. Ligation of the axillary artery is performed either in the first division of the vessel (above the pectoralis minor muscle) or in the third division (below the pectoralis minor muscle), where it lies on the tendon of the latissimus dorsi.

Infraclavicular ligation of the first division of the axillary artery is difficult because of the depth of the vessel, the many small vessels encountered in reaching it, and the narrow confines of the space in which the manipulations are conducted. After the shoulder has been drawn backward and upward, a curved incision is made from a point mesial to the coracoid process to a point just below the sternoclavicular joint. The clavicular portion of the pectoralis major muscle is exposed and is divided the full length of the wound. The pectoralis minor muscle is then identified and retracted downward. The coracoclavicular (clavipectoral) fascia, now exposed, is divided close to the coracoid process, care being taken not to wound the thoraco-acromial artery and the lateral anterior thoracic nerve emerging at this level. As the axillary vein comes into view behind the membrane, it is retracted mesially, and the artery is exposed. To accomplish the ligation, it may be necessary to bring the arm down to the side, since the vein tends to overlie and conceal the artery when the arm is abducted at a right angle to the trunk. The collateral circulation for ligation of this division of the artery is similar to that forced into play

are the antagonists of the trapezius and serratus anterior muscles; they rotate the scapula so that the lower angle passes backward and mesially. In paralysis of the rhomboid muscles the scapula on the injured side lies below its normal level, and its inferior angle is farther than normal from the median plane.

INTERMUSCULAR VASCULONEURAL PATHWAYS. The downward passage of the long head of the triceps muscle (p. 826) between the teres minor and major muscles forms two obliquely transverse intermuscular spaces. The quadrilateral *external axillary space* is bounded by the humerus, the long head of the triceps, and the minor and major teres muscles. Through the space pass the posterior humeral circumflex branch of the axillary artery and the axillary (circumflex) nerve. The triangular *medial axillary space* is bounded at the side by the long head of the triceps muscle, above by the teres minor, and below by the teres major. Through it emerges the circumflex scapular branch of the axillary artery. Below the teres major muscle is a *triangular triceps interspace* between the two heads of the triceps, through which run the superior profunda artery and the radial nerve (Fig. 751). These interspaces are the posterior exits of axillary infection.

VESSELS AND NERVES. The arteries to the scapular region (Fig. 752) are derived from two widely separated sources, the proximal subclavian and the terminal axillary arteries. They form an important collateral pathway which restores circulation to the upper extremity after ligation of either the subclavian or axillary trunks. The *transverse scapular* (*suprascapular*) *artery* is a branch of the thyrocervical trunk of the subclavian artery (p. 237). It reaches the region through the scapular incisura and ramifies over the posterior surface of the scapula. The *circumflex scapular* (*dorsal scapular*) *artery* from the axillary emerges through the medial axillary space and is distributed over the inferior part of the posterior surface of the scapula.

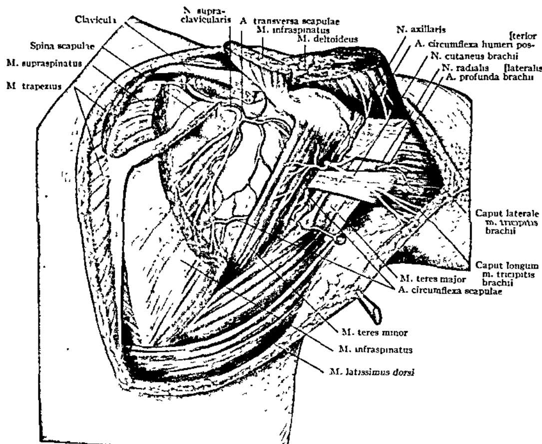


Fig. 752. DEEP STRUCTURES OF THE SCAPULAR REGION.
Parts of the trapezius, supraspinatus, infraspinatus and deltoid muscles have been removed.

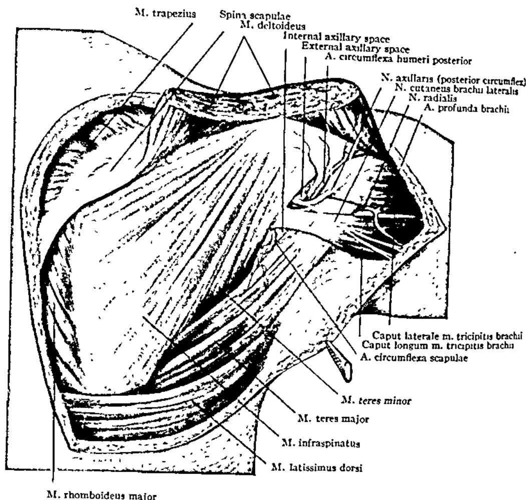


Fig. 751. SUPERFICIAL STRUCTURES OF THE SCAPULAR REGION.

spinatus muscle from the axillary margin of the scapula and inserts on the inferior facet of the greater tuberosity. It acts as a lateral rotator and adductor of the arm; its power of external rotation is increased proportionately as the arm is abducted. The *teres major muscle* (N. subscapularis, C 5, 6) arises from the inferior angle of the scapula and inserts into the mesial border of the intertubercular sulcus (bicipital groove). It adducts the arm and rotates it medially. The anterior scapular muscles are described with the costal and scapular walls of the axilla (p. 792).

The sheathing of the posterior scapular muscles within dense fascial and osteofascial compartments explains the clinical findings in the region. *Hemorrhage* from scapular fracture appears on the surface as trifling ecchymosis, and *tumors* from the fascial coverings may be mistaken for bony growths. The dense, overlying fascia is weakened above the transverse scapular (suprascapular) ligament where the transverse scapular (suprascapular) vessels enter the region. *Infection in the supraspinous fossa* generally passes through the scapular notch and points under the anterior border of the deltoid muscle near the coracoid process, or gravitates into the infraspinous fossa. The fascia is thin also at a point midway down the axillary margin of the scapula where the circumflex scapular (dorsal scapular) vessels pass to the dorsum of the scapula. An *abscess in the infraspinous fossa* is prevented from extending backward by the dense overlying fascia; hence pus follows the circumflex scapular vessels, gravitates downward, and points at the lower part of the posterior fold of the axilla. Infection in either fossa may escape outward toward the muscle insertions.

VERTEBROSCAPULAR MUSCLES. The *levator scapulae muscle* (C 3, 4) is inserted into the medial (superior) angle of the scapula. The *major* and *minor rhomboid muscles* (C 5) arise from the upper thoracic spines and insert into the vertebral margin of the scapula. The dorsal scapular nerve (to the rhomboids) passes down along the vertebral border of the scapula under these muscles. The vertebroscapular muscles

are the antagonists of the trapezius and serratus anterior muscles; they rotate the scapula so that the lower angle passes backward and mesially. In paralysis of the rhomboid muscles the scapula on the injured side lies below its normal level, and its inferior angle is farther than normal from the median plane.

INTERMUSCULAR VASCULONEURAL PATHWAYS. The downward passage of the long head of the triceps muscle (p. 826) between the teres minor and major muscles forms two obliquely transverse intermuscular spaces. The quadrilateral *external axillary space* is bounded by the humerus, the long head of the triceps, and the minor and major teres muscles. Through the space pass the posterior humeral circumflex branch of the axillary artery and the axillary (circumflex) nerve. The triangular *medial axillary space* is bounded at the side by the long head of the triceps muscle, above by the teres minor, and below by the teres major. Through it emerges the circumflex scapular branch of the axillary artery. Below the teres major muscle is a *triangular triceps interspace* between the two heads of the triceps, through which run the superior profunda artery and the radial nerve (Fig. 751). These interspaces are the posterior exits of axillary infection.

VESSELS AND NERVES. The arteries to the scapular region (Fig. 752) are derived from two widely separated sources, the proximal subclavian and the terminal axillary arteries. They form an important collateral pathway which restores circulation to the upper extremity after ligation of either the subclavian or axillary trunks. The *transverse scapular* (*suprascapular*) *artery* is a branch of the thyrocervical trunk of the subclavian artery (p. 237). It reaches the region through the scapular incisura and ramifies over the posterior surface of the scapula. The *circumflex scapular* (*dorsal scapular*) *artery* from the axillary emerges through the medial axillary space and is distributed over the inferior part of the posterior surface of the scapula.

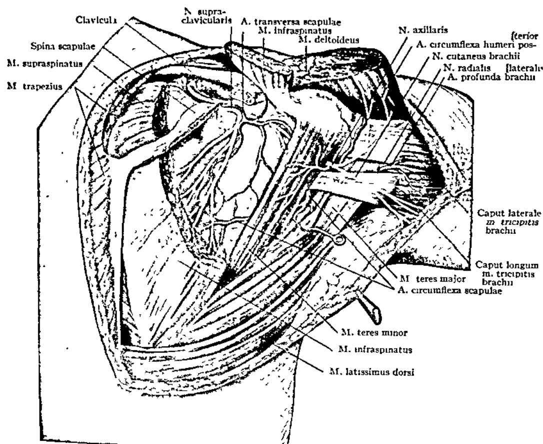


Fig. 752. DEEP STRUCTURES OF THE SCAPULAR REGION.

Parts of the trapezius, supraspinatus, infraspinatus and deltoid muscles have been removed.

The nerves are the suprascapular, axillary and radial. The *suprascapular nerve* runs with the transverse scapular artery and innervates the muscles of the scapular fossae. The *axillary (circumflex) nerve* leaves the axilla through the external axillary space with the posterior humeral circumflex artery and passes laterally upon the surgical neck of the humerus to supply the deltoid muscle. It gives branches to the teres minor muscle and the shoulder joint, and forms the lateral cutaneous nerves of the arm. The *radial nerve* passes downward with the profunda artery of the arm, supplies the long head of the triceps muscle, and gives off the posterior cutaneous nerve of the arm.

Fractures of the Scapula. Fracture of the scapula is rare because of the protective action of its intrinsic muscles and those connecting it with the trunk, and because of its mobility and the elasticity of the underlying chest wall. The most common variety is *transverse fracture of the body* of the scapula through the infraspinous fossa. Overlapping and angular projection of the fragments are prevented by the muscles which invest the bone and act as splints. An old method of examination suited to demonstration of fracture of this kind consists in gripping the acromion and outer end of the clavicle with one hand, drawing the shoulder backward, and grasping the prominent lower angle of the scapula with the other hand, and endeavoring to obtain preternatural mobility and possible crepitation. This procedure is unnecessary if a good roentgenographic examination can be obtained.

When fracture occurs in the *scapular neck*, which extends from the scapular notch to the upper part of the axillary border, almost parallel to the glenoid articular surface, the spine and acromion may be grasped with one hand and the proximal end of the humerus with the other. Crepitus sometimes can be elicited by moving the head of the humerus forward and backward. The degree of displacement of the detached fragment necessarily is limited because of the strong ligamentous connection interposed between the coracoid process and the clavicle. The *acromion process*, notwithstanding its exposed position, rarely is the site of fracture; but, when fracture does occur, there is little tendency toward displacement, because of the dense fibrous investment of that part of the scapula. It must be borne in mind that the acromial epiphysis may fail to unite with the spine of the scapula and be connected with it only by a layer of cartilage. The two may be connected by a distinct joint. When the presence of a movable acromion, especially with a history of trauma, suggests a fracture, the finding of bilateral un-united epiphyses is of great value in differential diagnosis. Normally, the acromial epiphysis begins to ossify about the fifteenth year and joins the spine about the twenty-fifth year.

Because of its sheltered position under the clavicle, the *coracoid process* is seldom injured. It may be broken off by an inward dislocation of the head of the humerus (p. 814). There is little displacement of the fragments unless the coracoclavicular ligament sustaining the process is broken. The ligament is steadied mesially by the pectoralis minor muscle. The distal fragment tends to be drawn downward by the weight of the arm and by the attachment of the coracobrachialis muscle and the short head of the biceps muscle to its tip. A sling for the forearm and a circular bandage about the chest usually are sufficient *treatment* for scapular fractures with little displacement.

Rupture of the Supraspinatus Tendon. To understand the pathologic change and the symptoms produced by rupture of the supraspinatus tendon, it is necessary to recall that the capsule of the shoulder joint in its superior and posterior portions blends with, and becomes indistinguishable from, the flat expanded tendons of the supraspinatus, infraspinatus and teres minor muscles as they pass to their insertions on the greater tuberosity of the humerus. The supraspinatus tendon lies above and forms the roof of the shoulder joint. It also forms a part of the floor of the subacromial bursa, which is interposed between the tendon and the acromion process and extends outward nearly 2.5 cm. between the greater tuberosity and the deltoid muscle. The function of the bursa is to facilitate movement of the greater tuberosity under the acromion in abduction of the shoulder.

Rupture of the supraspinatus tendon commonly takes place close to the greater tuberosity. The muscle then retracts, enlarging the separation and creating an opening of greater or less extent through which there is direct communication between the overlying bursa and the shoulder joint. In addition to large

complete ruptures, there probably are many small tears which involve only a few fibers of the tendon. Codman considers injuries of this type to be the most common cause of traumatic subdeltoid bursitis. Wilson is of the opinion that the tendon gradually deteriorates from excessive use and is attenuated by age, and that there probably is defective tendon circulation. It is likely that these changes precede and pave the way for rupture of the tendon; this view explains rupture occurring under normal use.

Meyer has described many examples of attrition affecting bursae, ligaments and tendons. He has described fraying and rupture of the tendon of the long head of the biceps, and occasionally in cadaver dissection has found the upper half of the shoulder joint destroyed. In these cases the supraspinatus tendon probably has been ruptured. Rupture of this tendon commonly is a lesion of late adult life and occurs in persons who have done heavy work. The rupture probably is produced in one of two ways: either by muscle strain when the arm is abducted, or by a direct blow upon the shoulder.

There may be only a small amount of pain associated with the tear. The history of a painful snap in the shoulder followed by noticeable weakness should suggest the possibility of supraspinatus tendon rupture. Continued disability following a fall on the shoulder, or the sudden onset of disability of the shoulder, should be regarded as suspicious of tendon rupture. Examination reveals atrophy of the shoulder muscles, most marked in the supraspinatus and infraspinatus regions. Palpation usually reveals a point of sharply localized tenderness over the tip of the greater tuberosity of the humerus, or just medial to it under the acromion. This may disappear when the tuberosity passes under the acromion. As the arm is moved actively through its range of motion, coarse crepitation in the region of the bursa is noted; this crepitation may be under the acromion. As the arm is moved passively forward and backward or in rotation, an unusual bony prominence can be felt to move under the examining fingers in the region of the subacromial bursa. This prominence is the greater tuberosity, which stands out definitely because of the gap in the supraspinatus tendon. A common finding is a lack of or weakness in active abduction, which is initiated by the supraspinatus muscle and completed by the deltoid muscle.

Contraction of the supraspinatus pulls the greater tuberosity under the acromion and abducts the arm through the first 15 degrees, from which level the deltoid muscle can complete the movement. The supraspinatus muscle also has the power of pulling the head of the humerus inward and fixing and stabilizing it in the glenoid fossa in active motion.

Operative *treatment* should be undertaken whenever function is reduced materially. It is possible to approximate the ruptured tendon by abducting the shoulder and pulling the tendon outward under considerable tension. The tuberosity usually is bare of tissue, and a firm point of attachment for the tendon can be secured only by drilling holes in the bone or grooving it to form broad contact with the flat sheet of tendon. It is necessary to provide a smooth floor for the new bursa so that movement of the tuberosity under the acromion will not cause pain.

Codman's saber-cut incision affords the exposure necessary and is also used for various arthrodeses of the shoulder joint. A wide exposure of the capsule and tendons overlying the humeral head is obtained, and the extent of the rupture of the supraspinatus tendon can be determined (Fig. 753). The healed fibrous edge of the opening is excised sufficiently to expose sound tendon tissue. With the arm in abduction, the edge of the tendon may be drawn outward to approximate the greater tuberosity without undue tension. With an osteotome a channel is cut in the anatomic neck of the humerus just proximal to the greater tuberosity to provide a bed for the edge of the tendon. Holes are drilled through the lateral edge of this groove. Sutures of fascia lata lace the tendon to the groove, leaving a smooth floor for the subacromial bursa and providing means for the tendon to become fixed to the bone throughout the length of the channel. The superficial structures are closed in layers after the parts have been fitted back normally. The shoulder should be fixed in 90 degrees' abduction, since recovery of function in the atrophied muscles is favored in a position of muscle relaxation.

CONGENITAL ELEVATION OF THE SCAPULA (SPRENGEL'S DEFORMITY). The congenital de-

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of the humerus, which marks the insertion of the deltoid muscle. Surgical interest in the region lies in the access it affords to the shoulder joint and the frequency of the involvement of the subacromial (subdeltoid) bursa.

SURFACE ANATOMY. The lateral margin of the acromial end of the clavicle is directed backward and overrides slightly the articular surface of the acromion. The *acromion process*, which forms the shoulder cap, is defined easily by palpation, and, where there has been much wasting of the tissue, stands out distinctly. Laxity of the acromioclavicular joint allows separation of the articular surfaces. The *coracoid process* of the scapula lies under cover of the anterior border of the deltoid muscle, but can be felt on direct downward and backward pressure 2.5 cm. below the clavicle, anterior to the outer curve. The *apex of the acromion* lies a little anterior to the acromioclavicular joint. The continuation of its lateral margin can be traced backward for about 5 cm. where it joins the inferior border of the scapular spine, which it meets at the sharp *acromial angle*. The small *acromial tubercle* at the angle is a useful landmark in taking measurements of the arm. The comparison of the distance between the acromial angle and the lateral condyle of the humerus on the two sides discloses any difference in length of the humerus.

The normal rounded contour of the shoulder is maintained by the proximal end of the humerus, over which the deltoid muscle is applied closely. In joint effusion (serous or purulent synovitis) the deltoid area is abnormally full and prominent, but fluctuation may be difficult to detect because of the overlying muscle. When the head of the humerus is dislocated mesially beneath the coracoid process or inferiorly beneath the glenoid fossa, the deltoid muscle no longer is prominent, but descends vertically from its upper to its lower attachment; the acromion is unduly prominent, and the shoulder is flattened.

Under normal conditions the head of the humerus is related closely to the under surface of the acromion and is felt rotating beneath it when the arm is moved. In deltoid paralysis

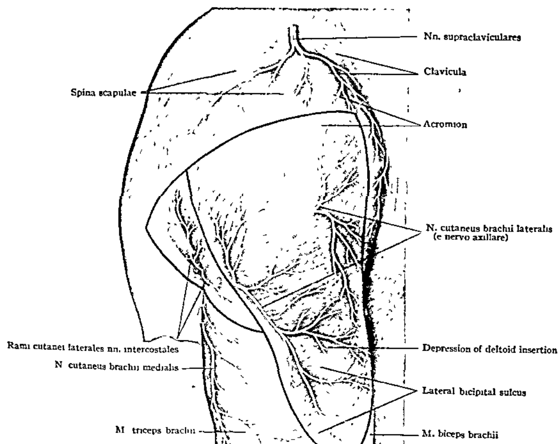


Fig. 754. SURFACE ANATOMY AND AREAS OF CUTANEOUS INNERVATION OF THE DELTOID REGION.

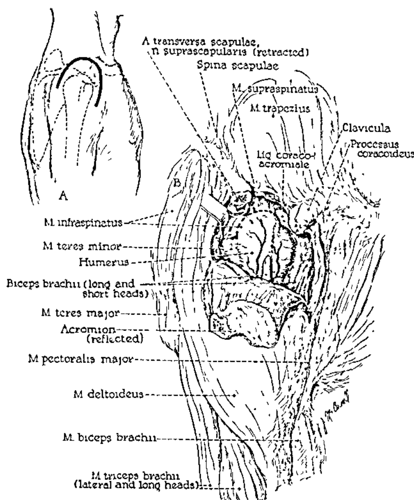


Fig. 753. SABER-CUT APPROACH TO THE SHOULDER JOINT.

A, An inverted U incision is made over the shoulder joint, beginning along the posterior third of the deltoid muscle not more than 2 inches below the level of the acromion, and carried upward and forward above the acromioclavicular joint and then downward along the anterior border of the deltoid for 3 inches. *B*, The posterior fibers of the deltoid are divided in line with the skin incision, the acromion process severed from the spine of the scapula with a Gigli saw, the acromioclavicular joint disarticulated, and the entire mass retracted laterally. Injury to the transverse scapular artery and supraclavicular nerves should be avoided. The joint capsule is incised (dotted line) along its superior surface.

The axillary nerve supplying the deltoid muscle enters posteriorly and passes along the deep surface of the muscle. If more than 2 inches of the muscle are cut posteriorly, then anterior fibers are deprived of their nerve supply. This is one disadvantage of the saber-cut incision.

formity of elevation of one scapula usually is associated with some degree of scoliosis. There may be associated anomalies of the face and skull, wryneck, or absence of bones and muscles. A bridge of bone sometimes connects the scapula with the vertebral column, or a piece of bone which does not articulate with the spine may project upward from the superior border of the scapula.

Because the scapula is elevated, the shoulder is carried high; the neck on the affected side is short and thick, and the trapezius muscle is prominent; the function of the arm is not impaired seriously. The superior border of the scapula is prominent and suggests the presence of an exostosis. The deformity may be bilateral.

Deltoid Region

The deltoid or lateral region of the shoulder is important functionally because of its powerful abductor mechanism. The region is outlined by the deltoid muscle and consequently is triangular. It is bounded above at its base by the outer third of the anterior margin of the clavicle, the apex and lateral border of the acromion, and the lower border of the spine of the scapula. It is limited below by a shallow depression, a little above the middle of the shaft

rior part of the capsule of the shoulder joint, forms much of the floor of this division of the bursa. The bursa almost disappears under the acromion when the arm is abducted to a right angle.

The supraspinatus and other tendon attachments to the greater tuberosity of the humerus may be torn in sudden motions or lesions about the shoulder. These lacerations tear the subacromial bursal floor and produce serious disability.

Inflammation of the subacromial bursa, *subacromial bursitis*, causes painful abduction and outward rotation of the arm. The painful stage of abduction is that which marks the passing of the greater tuberosity under the acromion, when the bursa is impinged against. Since an injury to the bursal floor brings the bursa into communication with the shoulder joint, the excess joint fluid remains in the joint when the arm is adducted, and the effusion cannot be detected. When the arm is abducted, the fluid is forced into the bursa and as a result forms an appreciable swelling beneath the deltoid muscle (Codman).

Any tear of the supraspinatus tendon renders abduction weak, except for that part of the motion performed by the deltoid muscle. If the laceration is extensive, abduction cannot

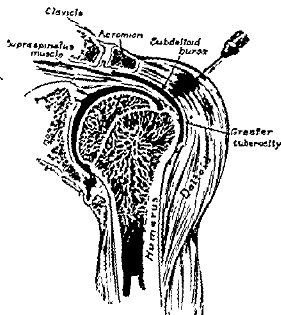


Fig. 756. FRONTAL SECTION THROUGH LEFT DELTOID AREA AT LEVEL OF SUPRASPINATUS TENDON.

(From Haldeman and Soto-Hall: J.A.M.A., 104: 2319–24, 1935.)

be initiated with the arm hanging at the side. Complete abduction, obtained passively, cannot be maintained against feeble downward pressure on the arm. This weakness is explained by the fact that the deltoid muscle cannot initiate abduction, or maintain it unless the supraspinatus tendon holds the humeral head firmly in the glenoid fossa.

Among the most common lesions about the shoulder joint is calcification in the supraspinatus tendon with a secondary bursitis involving the subdeltoid or subacromial bursa. This lesion results in pain localized to the shoulder and stiffness of the shoulder joint. The lesion is extra-articular and may either begin acutely or have an insidious, progressive onset. This lesion is a common condition and usually is not the result of a single blow or an infection, but follows a fatigue type of injury to the supraspinatus tendon at the point of its insertion into the greater tuberosity of the humerus. Such a fatigue injury frequently results from prolonged overhead work, requiring constant traction of the supraspinatus tendon to stabilize the shoulder in such activities as washing walls, ceilings or windows, painting, cleaning shelves and the like. As the result, some degeneration occurs at the point of insertion of the supraspinatus tendon into the greater tuberosity and results in minimal tearing of fibers with subsequent hemorrhage and calcium deposit. The subdeltoid bursa forms the roof of this portion of the supraspinatus tendon, and an acute bursitis results. The localized distention of the area accounts for the acute pain and the subsequent adhesive capsulitis and bursitis which later restrict motion of the shoulder joint.

In the acute phase pain and the painful restriction of shoulder joint motion are disabling and severe. At this stage several forms of treatment can give spectacular results, but at present the most satisfactory is that of needling the point of maximum tenderness, which localizes the acutely swollen and distended lesion, with 5 to 10 cc. of Novocain solution, making sure to puncture in multiple places this area of maximum tenderness to assure decompression of the confined area of swelling, releasing the fluid under tension into the large subdeltoid bursa, and following this through the same needle with the injection of 50 mg. of hydrocortisone solution. Frequently the results of a single needling are spectacular

and in deep anesthesia the interval between the acromion and humerus is increased, and the tip of the finger can be thrust into the intervening gap.

DELTOID MUSCLE. The deltoid muscle arises from an extensive V-shaped attachment from the anterior margin of the lateral part of the clavicle, the lateral border of the acromion, and the lateral border of the scapular spine (Fig. 751). It overlies and conceals the shoulder joint and gives the shoulder a smooth, convex contour. It converges to a pointed insertion on the *deltoid tuberosity* halfway down the lateral aspect of the humerus.

The deltoid muscle continues and maintains abduction of the humerus after its initiation by the supraspinatus. In complete abduction the arm is raised to an angle of about 180 degrees, the first 15 degrees of which are effected by the supraspinatus, the next 75 by the deltoid, and the remainder by rotation of the scapula by the trapezius and the serratus anterior muscles. The clavicular fibers of the deltoid are flexors and mesial rotators of the arm; the posterior fibers have an opposite action.

VESSELS AND NERVES. The *posterior circumflex artery* and the *axillary* (*circumflex*) *nerve* reach the deltoid region through the external axillary space (Fig. 752). They pursue a horizontal course forward beneath the deltoid, their path being indicated by a transverse line passing a little above the middle of the muscle. Incisions for approach to the shoulder joint should be made near the anterior border of the deltoid muscle to minimize damage to the axillary nerve. Results of injury to the axillary nerve are characteristic.

SUBACROMIAL (SUBDELTOID) BURSA. The subacromial bursa lies between the deep surface of the deltoid muscle, the acromial arch, and the lateral surface of the shoulder joint (Figs. 755, 756). It has subacromial and subdeltoid divisions which may be separated by a thin partition, but they so frequently communicate that the bursa should be considered a single space. The subacromial division lies between the deep surface of the acromion above and the insertion of the tendon of the supraspinatus muscle below. The supraspinatus tendon, which is fused into the supe-

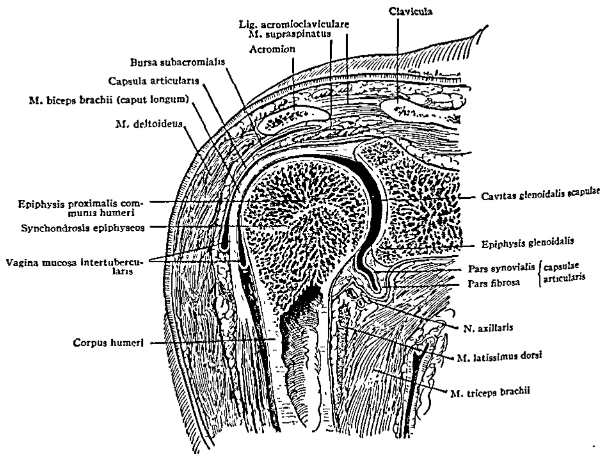


Fig. 755. FRONTAL SECTION THROUGH THE SHOULDER REGION.

This arrangement effectively prevents downward displacement of the acromial end of the clavicle. The slope of the articular surfaces explains also the common injury of *upward dislocation* of the *clavicle*. A force directed downward and mesially on the acromion thrusts it beneath the clavicle, tearing the reinforcing ligaments of the joint. An exaggerated upward displacement of the clavicle *indicates rupture of the coracoclavicular ligament.* The reduction of the dislocation is simple, but maintenance of proper position is extremely difficult. Any means by which the acromion can be drawn upward into its natural relations with the clavicle should be utilized. In an extreme form of this injury some type of operative treatment designed to draw the clavicle down to the coracoid process and maintain it in this position is indicated, since the coracoclavicular ligament usually is torn.

The CLAVICLE functions as a prop and keeps the acromion and shoulder joint at a distance from the trunk. The trapezius muscle supports the acromial end of the clavicle and helps to counteract the downward pull of the weight of the arm.

ARTICULAR EXTREMITIES OF THE SHOULDER JOINT. The glenoid cavity of the scapula articulates with the head of the humerus in a ball-and-socket joint (Fig. 757). The joint surface of the *articular extremity of the scapula* consists of the shallow glenoid fossa covered with cartilage and surrounded and deepened by the glenoid labrum (glenoid ligament). Between the glenoid fossa and the body of the scapula is a *constricted portion, the neck, marked by* superior and inferior glenoid tubercles for the attachment of the long head of the biceps muscle and the triceps muscle.

The joint surface of the *upper extremity of the humerus* is almost hemispherical and is directed upward, mesially and slightly backward. Its cartilaginous surface is large in comparison with that of the scapula; consequently only a small part remains in contact with the glenoid fossa at any one time. The head of the humerus is separated from the rest of the bone by a shallow groove or constriction, the anatomical neck, which encircles the articular margin. The anatomical neck is distinguished from the surgical neck, which is the cylindrical and somewhat constricted part of the shaft

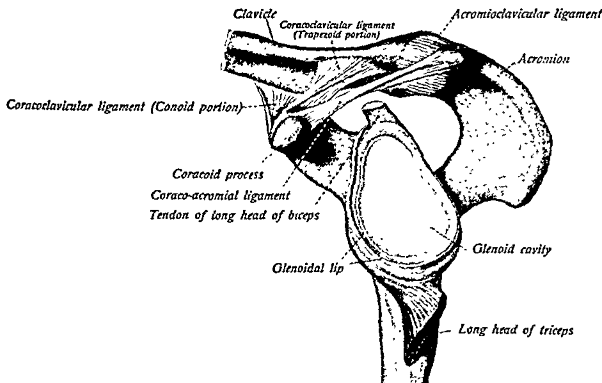


Fig. 757. SOCKET OF THE LEFT SHOULDER JOINT AFTER REMOVAL OF THE ARTICULAR CAPSULE AND THE TENDON OF THE BICEPS MUSCLE.

(Sobotta and McMurrich.)

Occasionally more pain is present for twelve to twenty-four hours after the first needling, but following this, relief is the rule. Occasionally repeated needlings at one- to two-week intervals for a total series of three to four needlings may be necessary. Another form of treatment in the acute stage is that of small doses of x-ray therapy to the point of tenderness over the shoulder joint. Occasionally, in the acute case, the calcium deposition into the hematoma and fluid which is confined in a small area under pressure can be aspirated with the needle. Many times, however, the calcification becomes thick and, later on, dehydrated and cannot be aspirated. It is not, however, necessary to obtain removal of the calcium deposit to give relief. Many times x-ray evidence of a calcium deposit in the region of the insertion of the supraspinatus tendon is present without a history of past or present acute symptoms.

Chronic, recurrent symptoms of pain and limitation of motion at the shoulder may occur; and because of pain over a period of a few weeks or a few months marked restriction of shoulder joint motion from a capsulitis occurs which is much more difficult to correct. In such a case the use of needling with Novocain and hydrocortisone injection is also advisable, together with physical therapy treatments in the form of heat, massage and stretching exercises to the shoulder with the patient carefully instructed on repeated, daily, home applications of dry or moist heat to the shoulder together with frequent daily active stretching exercises of the shoulder joint to maintain and improve shoulder joint motion. In the chronic case treatment may be necessary for three to six months before relief of pain and normal freedom of motion of the shoulder joint are completed.

A definite diagnosis must be made to account for the pain in the shoulder region and the limitation of motion. In addition to the calcification of the supraspinatus tendon with the secondary subacromial and subdeltoid bursitis and restriction of motion of the shoulder joint, other conditions may cause similar symptoms and would require a completely different approach to therapy. A cervical arthritis or cervical disk lesion would cause similar radiation of pain to the shoulder. Coronary artery disease may cause pain referred to the shoulder joint and restriction of motion of the shoulder as the result of the pain. Also, a malignant lesion in the breast might cause similar symptoms. A careful history to investigate these possibilities in the differential diagnosis, a physical examination, which includes examination of the cervical spine and the breasts, x-ray studies of both shoulders, with views made of each shoulder in both internal and external rotation, together with x-ray studies of the cervical spine, are important and necessary in the investigation of a patient complaining of pain in the shoulder and limitation of motion of the shoulder joint.

ANTERIOR APPROACH TO THE SHOULDER JOINT. The anterior approach to the shoulder joint is described on page 809. The anterior approach through Codman's saber-cut incision is described on page 801.

Bones and Joints

The bones and joints of the shoulder include the glenohumeral or true shoulder joint and the coraco-acromioclavicular arch, under which the shoulder joint functions.

ACROMIOCLAVICULAR JOINT AND THE CLAVICLE. The articular surfaces of the ACROMIOCLAVICULAR JOINT are oval and flat, and their axes are directed backward. They do not lie in the sagittal plane, but are directed obliquely so that the clavicular facet rests upon that of the acromion. The joint surfaces sometimes are separated by an interarticular cartilage. The joint margins are embraced by a weak *capsule*, thickened above and below by the *superior* and *inferior acromioclavicular ligaments* (Fig. 757). There is a sliding anteroposterior movement in this joint, so that, when the shoulder is thrust forward, the angle between the clavicle and acromion becomes smaller.

The joint is strengthened by the *coracoclavicular ligament*, which binds the upper surface of the coracoid process to the under surface of the clavicle near its acromial end. Much of the weight of the upper extremity is conveyed to the clavicle by this ligament. The joint is strengthened further by the *coracoacromial ligament*, which contributes to the formation of a strong arch above the shoulder joint and to prevention of upward dislocation of the head of the humerus.

A factor contributing to the security of this joint against trauma from above is the degree of obliquity with which the clavicular facet rests upon and is supported by the acromion

the biceps where the fluid gravitates along the synovial prolongation surrounding the tendon, and points opposite the tendon of the pectoralis major muscle or lower down on the inner aspect of the extremity. Joint suppuration may establish a fistula through the synovial prolongation. The joint may be aspirated just lateral to the tip of the coracoid process by directing the needle posteriorly, superiorly and laterally. The great vessels and nerves and the subacromial bursa thus are avoided.

STABILITY OF THE SHOULDER JOINT. The stability of the shoulder joint depends upon several factors. The *short scapular muscles*, which are connected intimately with the capsule, are important in maintaining the joint surfaces in contact. When they are severed, the head of the humerus falls away from the glenoid fossa. The stability provided by the *coraco-acromioclavicular arch* compensates, in a large measure, for the discrepancy in the sizes of the articular surfaces. On its under aspect the arch presents a smooth, concave surface with which the tendons of the short capsular muscles are in contact, and against which, through the intermedium of the subacromial bursa, they play in the various shoulder movements. The most important function of the arch is to protect the head of the humerus and prevent its upward displacement. The arch also prevents forward or backward displacement, since the coracoid and acromion processes descend lower than the summit of the head of the humerus. The *long head of the biceps*, which crosses the head of the humerus a little mesial to its center, acts as a steadying brace. It prevents any sudden impact between the head of the humerus and the overlying arch. If air enters the capsule, the cavity is converted from a potential to an actual one, and the laxity of the capsule allows the joint surfaces to fall widely apart.

MOVEMENTS. Movements at the shoulder joint are free—flexion, extension, abduction, adduction, circumduction and rotation being possible. They show a remarkable adaptability of structure to function. In *flexion* the arm can be moved forward through a semicircle from its position of rest beside the trunk. *Extension* has a limited range restrained by the anterior part of the capsule and by the contact of the head of the humerus with the coracoid process. Flexion and extension depend in large measure upon the mobility of the scapula. When the arm is flexed, the upper angle of the scapula moves backward and its inferior angle forward. Reverse movements occur in extension. These movements are favored by lax acromioclavicular ligaments and are restrained by the coracoclavicular ligaments. *Adduction* of the arm is prevented by contact with the side; adduction forward and medially is present, but is limited by the chest wall. *Abduction* is free and, like flexion, enjoys a semicircular range; the limit of abduction is reached with the arm vertically over the head and parallel to the long axis of the trunk. Contact of the humerus with the acromion limits the movement, as does the tension on the lower part of the capsule against which the joint surface of the humerus is brought into forcible contact. In all injuries about the shoulder, abduction and external rotation are the motions to be guarded. The large articular surface of the humeral head and the small glenoid socket favor *circumduction*. *Rotation* of the humeral head normally approximates 180 degrees.

Surgical Considerations

SURGICAL APPROACH TO THE ACROMIOCLAVICULAR JOINT AND CORACOCLAVICULAR LIGAMENT. The complete incision (Fig. 759) permits exposure and repair of dislocations of the acromioclavicular joint with accompanying separation of the coracoclavicular ligaments. This injury often follows a direct blow to the point of the shoulders; it is a relatively common football injury, often occurring as a result of a vicious tackle or a hard fall to the ground. A short version of this incision, exposing only the acromioclavicular joint and the distal third of the clavicle, is commonly used for excision of the end of the clavicle for painful arthritis of the acromioclavicular joint, for persistent dislocations of this joint and for comminuted fractures of the distal end of the clavicle.

SURGICAL APPROACHES TO THE SHOULDER JOINT. The *anterior approach* to the shoulder joint is through a vertical incision made in the anterior fibers of the deltoid muscle midway between the coracoid and the acromion processes (Fig. 760). This incision does little damage to the deltoid muscle or to its nerve supply. By rotating the arm mesially and laterally it is possible in joint resection to elevate the scapular muscles from the tubercles, either subcortically or subperiosteally. The external rotator muscles, the supraspinatus, infra-

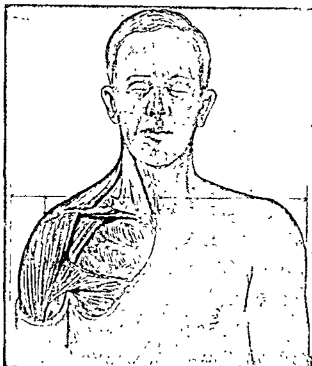


Fig. 758. USUAL DISPLACEMENT IN FRACTURE OF THE CLAVICLE.

In the usual displacement the proximal fragment is tilted up by the sternocleidomastoid muscle, and the distal fragment is depressed and carried inward by the weight of the arm and contraction of the pectoral teres major and latissimus dorsi muscles. (From Babcock: Textbook of Surgery.)

intervening between the tubercles and the insertions of the axillary muscles, the pectoralis major, the latissimus dorsi and the teres major.

Lateral and anterior to the head of the humerus are the greater and lesser tubercles (tuberosities). The greater tubercle continues downward as the lateral surface of the shaft, and the lesser tubercle looks directly forward. Into the greater tubercle insert the supraspinatus, infraspinatus and teres minor muscles (Fig. 752); to the lesser tubercle attaches the subscapularis muscle (Frontispiece, Part VIII).

At birth the upper extremity of the humerus is entirely cartilaginous. The *center of ossification* for the articular head appears during the first year; that for the greater tubercle in the second year; and that for the lesser tubercle at the end of the third year. These three centers unite during the seventh year to form the proximal epiphysis of the humerus. The epiphysis is concave on its under aspect and overlies the cone-shaped proximal end of the diaphysis like a cap. It fuses with the diaphysis between the eighteenth and twenty-fifth years. The epiphysial line is partly intracapsular and passes distal to the tubercles, but coincides medially with the margin of the articular head of the bone.

Between the tubercles the intertubercular sulcus (bicipital groove) is prolonged down the shaft; it lodges the tendon of the long head of the biceps, and has attached to its crests the tendons of the pectoralis major, latissimus dorsi and teres major muscles.

REINFORCING TENDONS AND THE CAPSULE OF THE SHOULDER JOINT. The capsule of the shoulder joint is not exposed fully until the tendons of the infraspinatus and teres minor muscles are separated or dissected away. These tendons fuse with and strongly reinforce the capsule. The subscapularis muscle differs from these muscles by being separated from the capsule by a large subscapular bursa. At the level of this bursa the capsule presents a deficiency of variable extent, through which a small pouch of synovia protrudes. The long tendon of the biceps muscle is an important accessory support of the joint. It is invested by a fold of joint synovia which is carried in the form of a tubular prolongation into the intertubercular sulcus and ends blindly opposite the insertion of the pectoralis major muscle.

The *capsule*, when divested of overlying tendons, appears large and remarkably loose, and is adapted to a wide range of joint movement, especially abduction. The scapular attachment of the capsule is applied to the bony rim of the glenoid fossa and to the labrum. The presence of the mesial part of the epiphysial line within the joint capsule explains the frequent extension of osteomyelitis of the shaft into the joint cavity. Because of the mode of capsular attachment, a separated epiphysis may carry with it a small portion of the shaft.

JOINT SYNOVIA. The synovial membrane lines the capsule throughout and is attached to the articular margins (Fig. 755). The long head of the biceps muscle arises from the uppermost point of the glenoid margin and traverses the joint. Although a portion of the tendon of the long head of the biceps is intracapsular, it remains extrasynovial. The synovial sheath and tendon are retained in the intertubercular sulcus by the transverse ligament, which is attached to both tubercles and bridges the sulcus. When this ligament is torn, the tendon of the long head of the biceps is displaced to the mesial side of the lesser tubercle.

In a thin person an *effusion* within the joint may be distinguished along the long head of

The disability occasioned by the detachment of the muscles in major resection is so great that the operation is rarely performed. Because internal rotation is performed mainly by the subscapularis muscle and external rotation by the infraspinatus and teres minor muscles, loss of their attachments produces a flail joint. The muscles of the axillary fold in no wise compensate for the loss of the rotators attached to the tuberosities.

Arthroplasty of the shoulder joint is rarely indicated, because of the more favorable results attending arthrodesis, in which a wide range of motion is attainable in the arm through the action of the scapulothoracic muscles, provided the humerus be ankylosed in abduction.

The *posterior approach* (of Kocher) is more difficult than the anterior, but gives freer access to, and more extensive exposure of, the joint. The approach is made by freeing the deltoid and trapezius muscles from the spine of the scapula, sawing or chiseling through the spine obliquely, and drawing the acromion process and deltoid muscle forward and laterally over the head of the humerus. Reflecting the acromiodeltoid flap laterally makes the head of the humerus, covered by the external rotator tendons, accessible in its upper, lateral and posterior aspects. The joint is opened from above where subsequent weakness matters least.

Codman's *saber-cut incision* is especially useful in the surgical repair of a torn musculotendinous cuff of the shoulder or in arthrodesis of the shoulder joint (Fig. 753).

ARTHRODESIS OF THE SHOULDER. The principal indication for an artificial bony union between the humerus and the glenoid (arthrodesis of the shoulder) is a flail arm which is not benefited by transplantation of the shoulder muscles to the humerus. The shoulder girdle has muscles capable of carrying the arm through its necessary ranges of movement

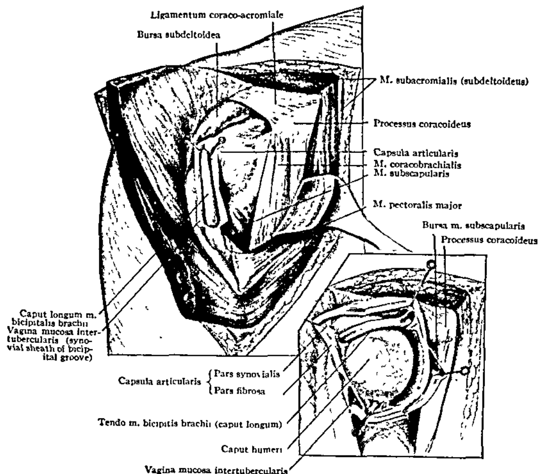


Fig. 760. ANTERIOR APPROACH TO THE SHOULDER JOINT.

Much of the insertion of the deltoid muscle along the clavicle has been divided to expose the joint more adequately.

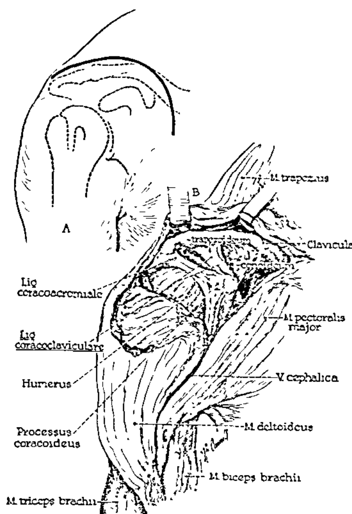


Fig. 759. ANTERIOR APPROACH TO THE ACROMIOCLAVICULAR JOINT AND CORACOCLAVICULAR LIGAMENT.

A, Supraclavicular incision along the superior surface of the acromion and the outer end of the clavicle. Medially, it curves downward along the line between the deltoid and the pectoralis major muscles. The cephalic vein should not be cut. *B*, The deltoid muscle is stripped subperiosteally from the anterior margins of the clavicle and the acromion and retracted downward. If necessary for the surgical procedures in mind, the trapezius is freed subperiosteally from the superior margins of the clavicle and acromion and retracted upward. The capsule of the acromioclavicular joint, the coracoid process and the trapezoid and conoid parts of the coracoclavicular ligament are thus brought into view.

spinatus and teres minor, are detached subperiosteally from the greater tubercle. The long head of the biceps muscle is retracted from its groove and drawn medially, and the subscapularis tendon is detached subperiosteally from the lesser tubercle.

The upper extremity of the humerus may be excised through the opening afforded in this way. The exact line of bone section depends upon the exigencies of the case. The favorite site of section is at the anatomical neck; section may have to traverse the tubercles or, occasionally, the surgical neck. Section through the surgical neck entails the loss of the fulcrum action of the humerus against the glenoid cavity, with loss of power in elevating the limb. With the biceps, coracobrachialis, pectoralis major, latissimus dorsi and teres major muscles preserved, the arm can perform most of its movements. Subperiosteal resection gives the best functional results. Removal of the glenoid fossa for tuberculosis is not easy by the anterior route.

An *antero-superomedial* approach to the shoulder joint allows greater access than can be obtained by the anterior approach alone (Fig. 761). This incision permits excellent exposure for exploration of the glenoid fossa and certain procedures for repair of recurrent dislocating shoulders. Hemorrhage during this operation comes from division of the acromial branches of the acromiothoracic artery and that branch of the anterior circumflex artery running in the intertubercular sulcus.

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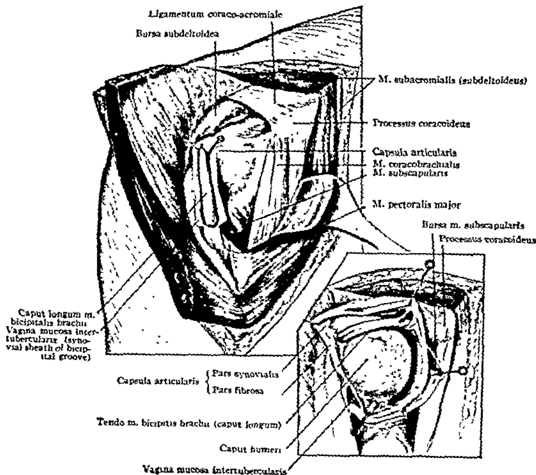


Fig. 760. Anterior approach to the shoulder joint.

Much of the insertion of the deltoid muscle along the clavicle has been divided to expose the joint more adequately.

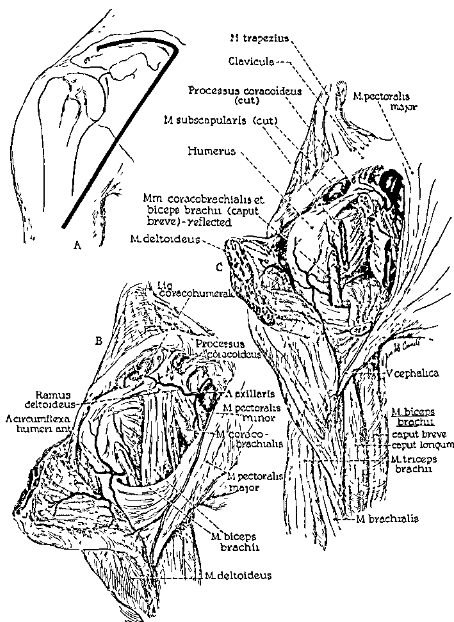


Fig. 761. ANTERO-SUPEROMEDIAL APPROACH TO THE SHOULDER JOINT (THOMPSON AND HENRY).

A, The incision starts at the acromioclavicular joint and extends medially along the anterior margin of the outer third of the clavicle, and then turns downward along the anterior margin of the deltoid muscle two thirds of the way to its insertion *B*, The interval between the anterior edge of the deltoid and the pectoralis major muscle is developed, and the deltoid retracted laterally. The cephalic vein and the deltoid branch of the thoracoacromial artery should not be injured. The attachment of the deltoid is then severed or stripped subperiosteally from the clavicle, and with lateral retraction of the muscle the region about the coracoid process and the anterior part of the joint capsule is exposed. *C*, For better exposure of the anterior aspect of the shoulder girdle the subscapularis is cut close to its insertion into the humerus, and, when necessary, the coracobrachialis and short head of the biceps may be detached with a portion of bone from the coracoid process and reflected downward.

if the joint between the humerus and scapula is obliterated. Arthrodesis is the procedure of preference in correction of paralyses of the upper arm caused by anterior poliomyelitis if the principal muscles which rotate the scapula are not paralyzed. The deltoid muscle usually is paralyzed, and there is no substitute for its action, since the supraspinatus muscle is too weak to carry out abduction. Ordinarily the trapezius muscle is not paralyzed because of the high level of its innervation, and the serratus anterior muscle generally is spared. These two muscles are the main rotators of the scapula and effect abduction if there is fixation of the glenohumeral joint. The main area of stability in this arthrodesis is that between the greater tuberosity of the humerus and the acromion process. This fusion materially

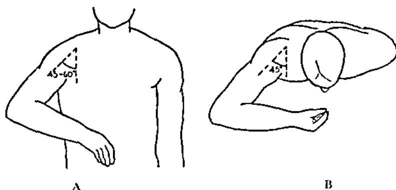


Fig. 762. OPTIMUM POSITION OF THE ARM IN ANKYLOSIS OF THE SHOULDER JOINT.
A, Position viewed from the front; *B*, position viewed from above. (Modified from McGregor.)

strengthens the bony fixation in the glenohumeral joint.

The optimum position for the arm in an ankylosed shoulder is abduction of about 45 degrees (Fig. 762). The arm should be 45 degrees forward of the frontal plane. The younger the patient, the greater should be the abduction angle.

EFFUSION IN THE SHOULDER JOINT. Effusions in the shoulder joint may result from injury or disease. They may be confused with accumulations of fluid in the subacromial bursa (p. 804). As the tension of the accumulating fluid increases, the arm is held in abduction to enable the capsule to accommodate it, and in this position fluctuation can be elicited. Fluid frequently follows the long head of the biceps muscle and forms a palpable swelling on the anterior surface of the arm. The effusion tends to escape through the weak areas of the capsule. It may communicate with the subacromial bursa and cause it to become distended.

A purulent effusion may work its way under the deltoid muscle and point on the skin at the anterior and posterior borders of the muscle or at the fold of the axilla. To avoid this complication, it is advisable to institute through-and-through drainage by way of the anterior approach. An instrument is passed through the joint so that it projects posteriorly below the tendon of the teres minor muscle; horizontal incision is then made over the instrument to avoid injury to the axillary (circumflex) nerve.

DISLOCATION AT THE SHOULDER JOINT. Glenohumeral dislocation is the commonest dislocation in spite of the stability of the shoulder joint (Fig. 763). Several factors contribute to the incidence of dislocations at this joint: it frequently is exposed to injury by falls on the outstretched hand, the elbow or the point of the shoulder, thrusting the head of the humerus against the capsule; the glenoid fossa is shallow and small in comparison with the hemispherical surface of the humeral head, making the joint union insecure; and the violence causing dislocation is unexpected, so that the reinforcing effect of the well-braced capsular muscles cannot be brought into play. Were it not for the great freedom of movement of the scapula on the chest wall and a considerable degree of motion at the acromioclavicular joint, dislocation at the shoulder joint would occur more frequently.

In childhood the capsule and reinforcements are stronger than the union between the epiphysis and diaphysis, and epiphysial separation is



Fig. 763. SUBCORACOID DISLOCATION OF THE LEFT HUMERUS.

Note the change in the axis of the left humerus and the method of palpating under the acromion, demonstrating the hollow on the left caused by absence of the humeral head from the glenoid fossa. (From Scudder: Treatment of Fractures.)

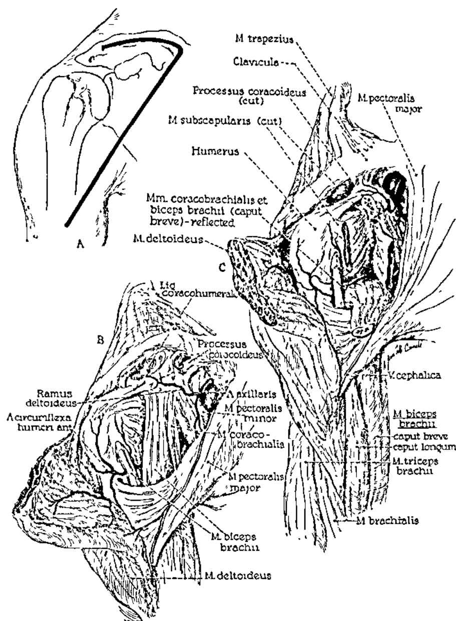


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attempts at reduction. The axillary nerve is exposed to pressure injury because of its proximity to the neck of the humerus.

In an examination for dislocation it is well to remember that the range of movement upon the affected side is decreased, and that there is inability to place the palm of the injured extremity upon the opposite shoulder with the elbow applied to the side of the chest.

Reduction of Dislocation of the Shoulder Joint. It is essential that x-ray films be taken of the shoulder before any attempt to reduce a primary dislocation of the shoulder joint or one that has occurred as the result of a severe injury. This will give the surgeon information about the type of dislocation as well as the presence or absence of fractures that may be associated with the dislocation. It is just as important to have x-ray pictures taken of the shoulder after the manipulation to have on record proof that the dislocation had been reduced, as well as further information about any fractures that might have been present and may not have been identified in the premanipulative films; and also if fractures had been present, that they had also been satisfactorily reduced. From a legal standpoint the proof that reduction had been accomplished as well as a satisfactory restoration of position of fractures might prove most important.

The direct method of reduction of an uncomplicated shoulder dislocation is effected by direct traction of the arm against the pull of the strong muscles maintaining the head of the humerus out of position. In this method an assistant steadies the patient's chest and exerts countertraction, while the operator exerts traction on the arm and manipulates the humerus with his foot in the patient's axilla. The initial steps consist in gentle abduction and slow, steady, firm traction on the arm to draw the head of the humerus free from the scapula, relax the deltoid and supraspinatus muscles, and stretch the subscapularis tendon and the lower part of the capsule (*cf.* Fig. 765). If the tear is through the anterior part of the capsule, reduction may occur without further manipulation; if it is through the inferior aspect of the capsule, the articular head is brought into contact with it by medial rotation. By continued traction on the arm, the subscapularis tendon is stretched tightly over the head of the humerus, pressing it through the rent in the capsule. Gentle continued traction and countertraction should be given time to work while the patient relaxes before any additional maneuvers are used. Certainly most dislocations can be reduced in this manner. General anesthesia is necessary and should always be used, unless repeated dislocations and reductions have made the restoration relatively easy.

The indirect method of reduction (of Kocher) is executed in four maneuvers (Fig. 766). In the *first maneuver* the arm is held as closely as possible against the side and drawn downward, fixing the distal end of the humerus so that the subsequent manipulations exert their maximum action on the head of the bone. For the *second maneuver* the patient's wrist is grasped so that the flexed forearm may be used as a lever to produce lateral rotation of the humerus, which is effected by carrying the forearm away from the chest until it lies almost in

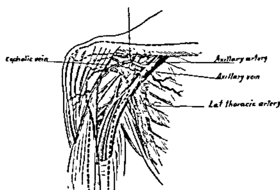


Fig. 764. RELATION OF THE BLOOD VESSELS AND NERVES TO THE HEAD OF THE HUMERUS.

(From Moorhead: Traumatic Surgery.)

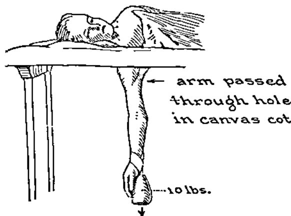


Fig. 765. STIMSON'S POSTURAL METHOD OF REDUCTION OF AN ANTERIOR DISLOCATION AT THE RIGHT SHOULDER JOINT.

more usual than dislocation. As age advances and joint stability is sacrificed for mobility, joint strength depends upon muscle support, and the common injury is dislocation.

The acromion usually forms the fulcrum for dislocation when the arm is in abduction. The shaft of the humerus forms the long arm of the lever, and the upper extremity of the humerus forms the short arm. In the production of the dislocation the long lever arm is thrust upward until it impinges against the acromion and causes the humeral head to tilt downward against the inferior part of the capsule, the only area not supported by tendons. The capsule gives way, and the humeral head passes through the tear and lies, for a time at least, below the glenoid fossa. It presses against the external (quadrilateral) space and comes into relationship with the axillary nerve (Fig. 752), which may be bruised or even ruptured. The head of the humerus may come to occupy an inferior, posterior or anterior position with reference to the glenoid fossa.

After rending the capsule below the subscapularis tendon and anterior to the triceps tendon, the head of the humerus may come to rest in the INFERIOR (SUBGLENOID) POSITION below and mesial to the glenoid fossa. The inferior margin of the glenoid fossa rests in the groove of the anatomical neck.

In POSTERIOR DISLOCATION the head of the humerus passes through the posterior part of the capsule and comes to rest on the posterior margin of the glenoid fossa, against the neck of the scapula under the acromion (subacromial) or in the infraspinous (subspinous) fossa anterior to the infraspinous muscle. The nature of the rotation of the humerus depends upon whether the subscapularis muscle is or is not ruptured.

Although most dislocations at first are subglenoid, the flexor and adductor muscles of the shoulder usually draw the head of the humerus into ANTERIOR and MEDIAL DISLOCATION. The head of the humerus is thrust through the anterior part of the capsule beneath the subscapularis muscle. The capsule is weak anteriorly and usually presents a small aperture through which the joint synovia communicates with the bursa beneath the subscapularis muscle (p. 793). In anterior displacement the head of the bone may occupy several positions. As the humeral head leaves the glenoid fossa, it descends a little to pass beneath the coracoid process. If displacement is arrested at this point, the dislocation is *subcoracoid*, and the humeral head lies beneath the subscapularis tendon and anterior to the neck of the scapula. The humerus is rotated laterally because of the stretching of the infraspinatus and teres minor tendons. The posterior part of the capsule is stretched taut against the posterior rim of the glenoid fossa, and the posterior part of the anatomical neck rests against the forward border of the glenoid.

The head of the humerus may be carried still further mesially and for the most part lie to the mesial side of the coracoid process. The anatomical neck rests upon the anterior surface of the neck of the scapula or against the forward part of the glenoid rim as in the last instance, but with more medial rotation of the humerus. There usually is a concomitant deflection of the biceps tendon downward and medially from its normal course. The lateral rotators of the arm are overstretched; if they do not give way, the whole or a part of the greater tubercle may be torn away (fracture-dislocation). The subscapularis muscle in these dislocations is stretched or lacerated by the head of the humerus. Displacement further medially occasionally is observed when the head of the humerus is carried more completely into the axilla and upward toward the clavicle into the interval between the serratus anterior and pectoral muscles. The *subclavicular* variety of dislocation ordinarily is associated with extensive tearing of the capsule and the capsular muscles.

In all forward displacements the normal rounded contour of the shoulder is lost. The humeral head is drawn mesially so that the deltoid muscle no longer is molded over the greater tubercle, but drops straight downward from the acromion. The outer margin of the acromion, now the outermost bony point of the shoulder, becomes prominent, and a ruler can be made to touch both the acromion process and the lateral condyle of the humerus. In extreme forward and mesial displacement the head of the humerus produces a rounded elevation in the superficial infraclavicular area.

The displaced humeral head may press upon the axillary vessels, causing an edematous or gangrenous condition of the limb (Fig. 764). In old unreduced dislocations the axillary vessels may adhere to the fibrous tissue about the humerus and be injured in subsequent

Dislocation with fracture of the surgical neck of the humerus almost always must be reduced by open operation, since the small proximal fragment assumes a position that renders manipulative reduction impossible. If the bony fragment torn away includes the supraspinatus insertion, the fragment may be drawn upward under the acromion process and subsequently limit abduction. Early open reduction with replacement of the greater tubercle should be carried out to prevent limitation of abduction. In long-standing dislocations with fibrous adhesions the lateral rotation in Kocher's method of reduction exerts a powerful twist on the humerus and may cause a spiral fracture of the surgical neck. In the direct method of reduction with the foot in the axilla the reducing force is exerted along the long axis of the shaft and therefore incurs little danger of fracture.

Fracture of the Clavicle. The clavicle is fractured more frequently than any other bone in the body. The bone is fixed at its sternal extremity by strong ligaments, and may be compressed by indirect violence exerted along its long axis until it gives way at its weakest point. Fracture sometimes is caused by direct trauma. The usual location of fracture is at the junction of the middle and outer thirds of the bone; it is therefore mesial to the coracoclavicular ligaments (Fig. 767). As a rule, the fragments are displaced markedly by the combined effect of muscle pull and the weight of the extremity. The displacement is confined chiefly to the outer fragment, which is drawn downward and medially. The trapezius muscle, acting on the shoulder girdle, one arch of which is broken, is unable to support the weight of the upper extremity. The mesial displacement of the outer fragment is increased by the mesial pull of the axillary muscles.

Fracture may occur lateral to the ligament, and the medial fragment be elevated slightly above the lateral, but the up-and-down displacement is not conspicuous. The anteroposterior displacement may be marked and the lateral fragment be tilted sharply medially at the site of fracture, even forming a right angle with the medial fragment. When fracture occurs between the two components of the coracoclavicular ligament, there is little displacement. Complications rarely attend these fractures unless they are comminuted and a fragment is driven into the subclavian vessels or into the brachial plexus.

The *treatment* of clavicular fractures is troublesome, because there is no way of splinting the broken bone directly; closed reduction can be made only by pushing the shoulder backward until the two fragments come into apposition and anatomic alignment. Reduction of the fracture in the recumbent position best brings about accurate replacement, because the muscles are relaxed and the weight of the arm does not act to produce displacement. The clavicular cross is not a satisfactory method of treatment. A well applied and padded figure-of-eight plaster bandage to hold the shoulder back makes a satisfactory ambulatory splint and will reduce and hold most simple fractures. If marked malposition cannot be corrected, an open reduction with an intramedullary wire fixation is advisable.

Fractures of the Proximal End of the Humerus. In injuries about any articular extremity the plane of the epiphysis and the

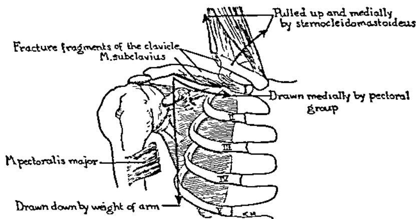
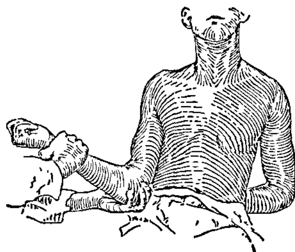
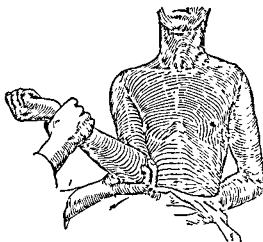


Fig. 767. Mechanism of fragment displacement in fracture of the clavicle just lateral to the attachment of the sternocleidomastoid muscle.



a



b



c

Fig. 766. KOCHER METHOD OF REDUCING A SUBCORACOID DISLOCATION OF THE HUMERUS.

a, With the elbow fixed against the chest, the arm is laterally rotated. *b*, Next, while the arm is in the position of lateral rotation, the elbow is carried forward and medialward on the chest. *c*, Finally, the arm is elevated across the chest, and the forearm is rotated medially. (From Babcock: Textbook of Surgery.)

the frontal plane. The motion is performed slowly to overcome gradually the restraining muscle spasm of the adductors of the arm. This maneuver elevates the anatomical neck from the glenoid margin and brings the posterior aspect of the greater tubercle against the articular surface of the glenoid fossa, from which it is separated by a part of the capsule. If the tear involves the anterior part of the capsule, the subscapularis tendon, made tense by the extreme outward rotation, may press the head back into place.

If reduction has not occurred, a *third maneuver* is used. The elbow is carried mesially across the chest; lateral rotation of the arm is maintained by the position of the forearm. This movement of flexion and adduction of the arm stretches the capsule by tilting the greater tubercle backward and usually causes the head to drop into place. If reduction then has not taken place, a *fourth maneuver* is performed The forearm is pressed rapidly over to the opposite shoulder to cause mesial rotation of the humerus. By elevating the elbow slightly during this movement, the humeral head descends as it rotates mesially and passes through the rent in the inferior part of the capsule.

Shoulder DISLOCATION COMPLICATED BY AVULSION OF THE GREATER TUBERCLE sometimes occurs. The difficulty of treating this combined lesion lies not in the reduction of the dislocation, but in the maintenance of the arm in adduction to obtain satisfactory healing of the fracture. Abduction is definitely unfavorable to repair of the torn capsule, and, as a compromise, the arm is kept in adduction for sufficient time, usually three weeks, to assure repair of the capsule; abduction is then begun gradually to restore motion at the shoulder joint.

tion. In uncomplicated *avulsion of the tubercle* the tendency to abduction and external rotation, caused by the action of the muscles inserting on the greater tubercle, is corrected readily by bringing the arm to the side, rotating it mesially, and securing it comfortably to the side of the chest.

The surgical neck of the humerus is that considerable expanse of bone extending from the lower limit of the tuberosities to the insertion of the axillary muscles into the intertubercular sulcus. FRACTURE OF THE SURGICAL NECK (Figs. 768 to 770) often results from indirect violence, such as a fall upon the elbow with the arm abducted. When the muscles and ligaments are sufficiently strong to maintain the humeral head in the socket, undue stress falls upon the surgical neck. The acting force is that which ordinarily would cause a shoulder dislocation.

The proximal fragment of the fracture is abducted slightly by the supraspinatus muscle, but is rotated laterally only to the degree that the lateral rotators attached to the greater tubercle overcome the pull of the subscapularis muscle attached to the lesser tubercle. The distal fragment is adducted and rotated mesially by the muscles inserted into the intertubercular sulcus (bicipital groove), and is drawn proximally (to the extent of arm shortening) by the biceps, triceps, coracobrachialis and deltoid muscles. To reduce the fracture, the distal fragment must be drawn downward, abducted, manipulated into apposition with the proximal fragment, and brought into that degree of lateral rotation which will bring the tip of the external condyle into the normal straight-line relation with the greater tubercle and the acromial angle. Without restoration of normal bony relationships, union occurs with considerable deformity and limitation of motion.

In general, in fractures of the surgical neck and below, the humerus can best be treated with a slight hanging cast or collar-cuff sling, which exerts constant, steady traction of a desired amount to the fracture site to maintain length and alignment. This also permits shoulder motion to be started and continued as soon as pain permits. In an elderly patient whose muscle tone is not strong the simple use of a collar-cuff sling, which permits the arm to hang freely and the weight of the arm itself to serve as traction, is satisfactory. In a more muscular patient a long arm cast, holding the elbow at 90 degrees of flexion and with the forearm in supination and attaching a collar-cuff sling to this, will give additional weight to counterbalance the tone of the muscles. In using the hanging cast it is most necessary to instruct the patient properly on its use, in that the arm should be left in a hanging position at all times, at least for the first three weeks, to prevent angulation and loss of traction at the fracture site. This is best accomplished at night by having the patient sit in a chair with the arm hanging freely and not resting on a

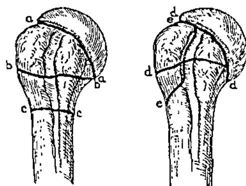


Fig. 769. COMMONEST FRACTURES ABOUT THE UPPER END OF THE HUMERUS.

a–a, Fracture of the anatomical neck; *b–b*, transverse fracture through the tubercles; *c–c*, fracture of the surgical neck; *d–d–d*, Y fracture; *e–e*, fracture of the greater tubercle.

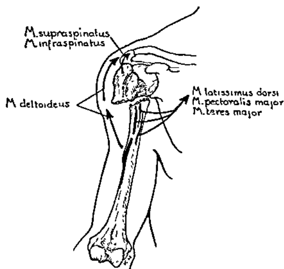


Fig. 770. FRACTURE OF THE HUMERUS THROUGH THE SURGICAL NECK.

The proximal fragment is abducted slightly by the supraspinatus muscle. The distal fragment is adducted and rotated mesially by the axillary fold muscles which insert into the intertubercular sulcus.

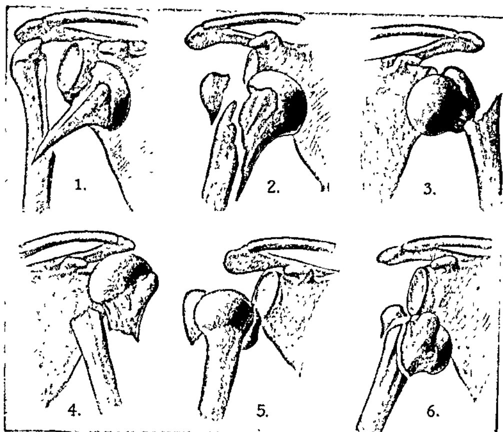


Fig. 768. VARIOUS FRACTURES OF THE UPPER END OF THE HUMERUS, ASSOCIATED WITH DISLOCATION OF THE HEAD OF THE HUMERUS.

1, Split fracture of the shaft of the humerus with subcoracoid dislocation of the head; 2, oblique fracture of the upper end of the humerus with subcoracoid dislocation and separation of the greater tuberosity; 3, fracture of the surgical neck of the humerus, with dislocation of the head; 4, fracture to the surgical neck of the humerus, with upward displacement of the head and medial displacement of the shaft; 5, subglenoid dislocation of the humerus, with separation of the greater tuberosity to the lateral side and of the lesser tuberosity to the medial side; 6, subglenoid dislocation of the humerus with fracture of the anatomical neck and separation of the greater tuberosity. (Robert Jones.)

attachment of the joint capsule must be considered. In the humerus the epiphysial line passes distal to the tubercles, but on the medial side it coincides with the margin of the humeral head. The capsule is attached to the anatomical neck, except at the mesial margin, where it embraces a small part of the shaft.

In FRACTURES OF THE ANATOMICAL NECK OF THE HUMERUS (Figs. 768, 769), which occur chiefly in the aged, the proximal fragment may embrace a portion of the tubercles or varying amounts of the surgical neck. The shaft usually is driven into the head of the bone with considerable impaction, because the most common cause of the fracture is a fall upon the shoulder. If impaction does not occur and the joint capsule is detached completely from the upper fragment, necrosis of the fragment results, since there is no direct blood supply to the head of the humerus. Usually a portion of the periosteum and part of the capsule on the inner side of the fragment remain, so that a blood supply is maintained and union occurs.

Treatment is directed toward regaining the use of the shoulder rather than toward care of the fracture. It is important to prevent the breaking-up of an impaction with possible consequent elimination of the blood supply of the proximal fragment.

In FRACTURE OF THE TUBERCLES uncomplicated by dislocation of the head of the humerus, the arm is drawn in the direction of the pull of the intact muscles. With the *greater tubercle torn away*, the supraspinatus, infraspinatus and teres minor muscles draw the fragment upward and backward out of control, and the arm is rotated mesially by the pull of the intact subscapularis muscle. To secure approximation of the separated fragments, the arm must be brought into abduction and external rota-

ing the lower extremity of the vertical limb of the first incision. The second incision is carried horizontally across the inner aspect of the limb and along the axilla to meet the horizontal portion of the first incision. The incision forming the queue of the racket is deepened to the bone, and the outer or deltoid flap, containing the axillary (circumflex) vessels and nerves, is raised from contact with the humerus. The axillary vessels, median basilic vein and acromiothoracic artery are ligated and divided where they emerge beneath the pectoralis minor muscle. The terminal nerves of the brachial plexus are drawn downward, ligated, divided, and allowed to retract into the apex of the axilla or behind the clavicle.

In *disarticulation of the humerus* the coracobrachialis muscle and the short head of the biceps muscle are divided near their origin at the coracoid process. By abducting and rotating the arm, using internal and external rotation alternately, the capsular muscles, the long head of the biceps, the subscapularis and the joint capsule can be divided and the head of the humerus be disarticulated. While the arm is held away from the side, the attachments of the latissimus dorsi and teres major muscles and the long and short heads of the triceps muscle on the posterior aspect of the limb are divided. The tendons of the pectoralis major and the latissimus dorsi muscles with the intrinsic scapular muscles are sutured into the margins of the glenoid fossa. The deltoid muscle flap is refashioned to fill the space from which the humeral head is removed.

In *amputation of the humerus through the surgical neck* the pectoralis major muscle is cut from its humeral attachment, and the axillary and thoraco-acromial vessels and median basilic veins are ligated. The nerves are divided as for disarticulation. With the arm well abducted, the teres major and latissimus dorsi muscles are cut at their insertions into the intertubercular sulcus. The biceps, triceps and coracobrachialis muscles are cut to retract to the saw line at the surgical neck. The deltoid muscle flap is sutured over the bone end, and the latissimus dorsi and pectoralis major muscles are sutured into the stump posteriorly.

Amputation through the surgical neck, although having no stump length and no value from a prosthetic standpoint, is preferable to disarticulation, because there is less danger incident to dead space, and less atrophy in the shoulder girdle.

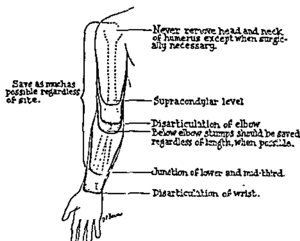


Fig. 772. SITES OF MAJOR AMPUTATIONS IN THE UPPER EXTREMITY.
(From Alldredge: Surg., Gynec. & Obst., 84: 759–64, 1947.)

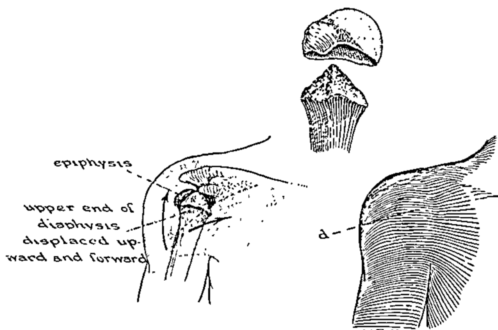


Fig. 771. SEPARATION OF THE UPPER EPIPHYSIS OF THE HUMERUS.

The inset shows the normal cup and cone formed by the epiphysis and the shaft of the humerus. This conformation may render reduction difficult, but retention after reduction easy; *d*, the prominence from the displaced diaphysis. (From Babcock: Textbook of Surgery.)

table or an arm rest. In the case of multiple injuries, when the patient is required to remain in bed, traction to the cast with a loop at the elbow and the weight extending from the foot of the bed will give a similar, although not as efficient, form of traction to the fracture site. Within a week after the application of a hanging cast or as soon as acute pain has subsided the patient should be carefully instructed on the use of circumduction exercises to be carried out many times each day in order to maintain as much motion in the shoulder joint as possible to limit the disability following healing of the fracture.

SEPARATION OF THE UPPER EPIPHYSIS OF THE HUMERUS. Separation of the upper epiphysis of the humerus (Fig. 771) usually occurs at some period before the twenty-fifth year of life. Since the epiphysis includes the tubercles to which the scapular cone of rotator muscles is attached, complete separation causes abduction and forward tilting of the distal end of the head. The shaft rides past the head mesially. To reduce the deformity, the arm is abducted, and pressure is made on the proximal end of the shaft to turn it into its conical socket in the epiphysis. This injury may be followed by permanent shortening of the limb through premature ossification of the epiphysial cartilage.

DISARTICULATION OF THE HUMERUS AT THE SHOULDER JOINT; AMPUTATION THROUGH THE SURGICAL NECK OF THE HUMERUS. The sites of election for amputation of the upper extremity are well defined (Fig. 772), and the *essentials in amputations* are presented later (p. 832).

The same incision is used in shoulder joint disarticulation as for amputation through the surgical neck of the humerus. The disarticulation should never be done except when absolutely necessary, it being always better to conserve the head and the neck of the humerus for the sake of contour and normal appearance. This also allows for better prosthetic fitting and improved prosthetic accomplishment. An anterior racket incision is made with the arm in moderate abduction and lateral rotation. The incision marking out the handle of the racket begins immediately below and to the lateral side of the tip of the coracoid process, and passes downward between the anterior fibers of the deltoid muscle and the tendon of the pectoralis major muscle. Just below the anterior axillary fold the incision curves horizontally outward across the anterior aspect of the limb through the superficial tissues and lower part of the deltoid muscle to meet the posterior axillary fold. Starting again at the queue of the racket with the arm in extreme abduction, a second incision is made continu-

superficial guide to the brachial vessels and the median nerve

The *lateral bicipital sulcus*, shorter and less distinct than the medial, begins at the depression in the middle of the arm, which marks the insertion of the deltoid muscle, and ends anterior to the bend of the elbow. The groove, in its lower part, separates the brachioradialis (supinator longus) muscle and the radial extensor muscles from the biceps muscle. The cephalic vein ascends in this sulcus to its upper extremity and then follows the anterior border of the deltoid muscle.

The typical, regularly illustrated, course of

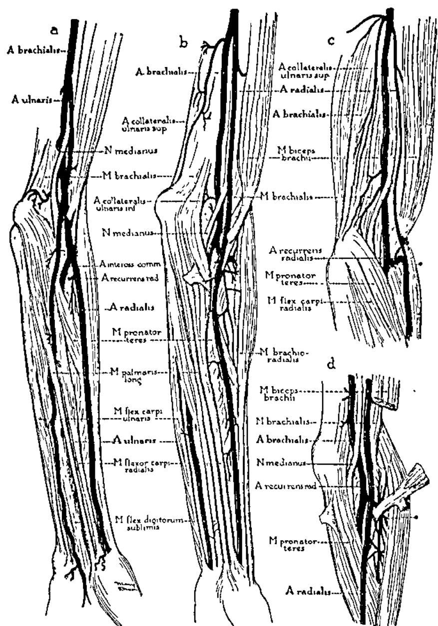


Fig. 774. EXAMPLES OF VARIATION IN THE LEVEL OF DIVISION OF THE BRACHIAL ARTERY, ARRANGED IN THE ORDER OF PROGRESSIVELY HIGHER DIVISION.

In addition to variation in the point of origin, from the main stem, of the radial and ulnar divisions, the following departures from the anatomic norm are recorded: in *a*, course of the ulnar artery superficial to 3 of the 4 muscles which constitute the first layer of the flexor-pronator set; in *c*, the occurrence of a superficial radial artery, which, while slight in caliber in its brachial portion, continues as a large vessel distal to the point of communication (at *) in the cubital fossa, with the brachial artery; in *d*, the occurrence of a communication (at *), distal to the cubital fossa, between a large radial artery and the volar interosseous artery. (From McCormack, Cauldwell and Anson: Surg., Gynec. & Obst., 96: 43-54, 1953.)

CHAPTER 28

Arm or Brachial Region

SURFACE ANATOMY. The arm in strong adult males is flattened from side to side, because of the grouping of the arm muscles anterior and posterior to the humerus (Fig. 773). The varying degree of fullness anteriorly corresponds to the fleshy belly of the *biceps brachii muscle.*

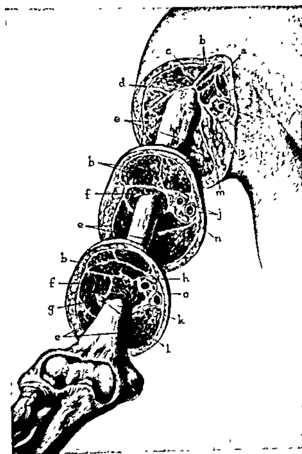


Fig. 773. TRANSVERSE SECTIONS THROUGH QUARTERS OF THE ARM, SHOWING THE STRUCTURES WHICH APPEAR AT REPRESENTATIVE LEVELS OF AMPUTATION.

Key: *a*, coracobrachialis muscle; *b*, biceps brachii; *c*, pectoralis major; *d*, deltoideus; *e*, triceps brachii; *f*, brachialis; *g*, brachioradialis; *h*, musculocutaneous nerve; *i*, median nerve; *j*, brachial artery and veins; *k*, ulnar nerve; *l*, radial nerve; *m*, teres major muscle; *n*, medial brachial cutaneous nerve; *o*, medial antebrachial cutaneous nerve. (After Lanz and Wachsmuth.)

When the biceps is thrown into action by forcible flexion of the arm at the elbow, the fullness is accentuated. The upward slope of the fullness is lost under the anterior surface of the deltoid muscle. Below the center of the arm the biceps narrows sharply into a rounded tendon which dips backward into the antecubital fossa anterior to the elbow. The lateral margin of the biceps tendon is the more distinct, since the medial margin is somewhat obscured by the lacertus fibrosus, which binds it to the deep fascia of the forearm.

The fullness over the posterior aspect of the arm is most marked at its center and is the fleshy mass of the *triceps brachii muscle.* Below this fullness the surface of the arm presents a flattened appearance which corresponds to the triceps tendon. With the elbow in forcible extension against resistance, the lateral head of the triceps muscle causes a definite prominence, parallel to and below the posterior border of the deltoid muscle. The long head of the triceps can be made out as it emerges from beneath the posterior border of the deltoid muscle. The muscle mass on the posteromesial aspect of the arm is the medial head of the triceps.

The *medial bicipital sulcus* begins in front of the posterior axillary fold and descends along the inner aspect of the arm as far as the lower third, where it inclines obliquely forward, terminating at the center of the bend of the elbow. It separates the coracobrachialis and biceps muscles in front from the triceps muscle behind, and, toward its termination, defines the line of separation between the biceps and the pronator teres. Superiorly, the groove is obscured by the coracobrachialis muscle, which can be brought into relief when the abducted arm is adducted against resistance. The sulcus indicates the course of the basilic vein toward the axillary vein and is the

the brachial artery. Either of the heads of the belly of the muscle, or the muscle body itself, may be ruptured by violent muscle effort. Weakness in flexion and forced supination of the forearm result.

Variations from the anatomic norm were found in twenty-eight of 130 specimens (22 per cent) of biceps brachii muscle studied in a consecutive series. In five, variations occurred bilaterally, but symmetrically in only three of the five.

The presence of an accessory head of humeral origin represented the commonest departure from the "standard," regularly described, form of the biceps.

In those few instances in which the muscle was quadricipital rather than bicipital, the two accessory heads were of humeral origin.

Supernumerary heads of origin, derived from the shaft of the humerus, were encountered in eighteen of 130 upper extremities, in the following order of decreasing frequency: one supernumerary head in eleven instances (Fig. 777, *a*, *d*); two accessory heads in five cases (Fig. 777, *b*, *c*); three such heads in two extremities (Fig. 778, *a*). In two instances an accessory head arose proximally from the bicipital groove of the humerus (Fig. 778, *c*). In each of the five cases in which the accessory head arose from another muscle, the muscle offering subsidiary attachment was the pectoralis major (Fig. 778, *b*). A replacing head occurred in three specimens, arising in each from the intertubercular sulcus (Fig. 778, *d*).

Considered on the basis of parts, it was found that variation in the short head of the muscle affected chiefly its relation to the contiguous origin of the coracobrachialis, the latter muscle seeming then to be derived from the biceps rather than being merely fused with it at the scapular (coracoid) origin. In the case of the long head, on the contrary, doubling was the most frequent variation, the accessory head arising from the overlying pectoralis major or from the intertubercular sulcus transmission of the normal head from the scapular (supraglenoid) origin.

Among the more striking variations described by some investigators which were not encountered in this series are the following: absence of the entire muscle or of its short portion; complete separateness of the heads;

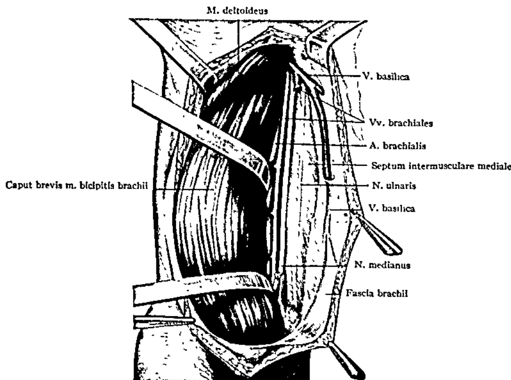


Fig. 776. STRUCTURES IN THE ANTERIOR COMPARTMENT OF THE RIGHT ARM.
The biceps muscle is retracted laterally, exposing the brachial vessels and the median nerve. The ulnar nerve is shown as a transparency through the medial intermuscular septum.

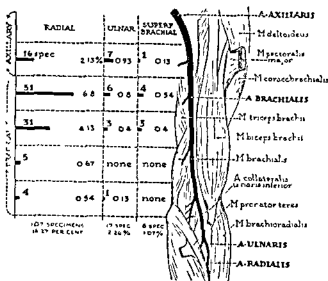


Fig. 775. VARIATIONS IN ORIGIN OF THE BRANCHES OF THE BRACHIAL ARTERY.

(From McCormack, Cauldwell and Anson: Surg., Gynec. & Obst., 96: 43-54, 1953.)

the *brachial artery* and the *median nerve* lies along a line, drawn on the inner aspect of the abducted arm, from a point anterior to the posterior axillary fold to the center of the bend of the elbow (antecubital fossa). Actually, departures from the accepted pattern are common, especially in the case of the brachial artery (Figs. 774, 775). The *ulnar nerve* follows the course of the artery in the upper third of the arm, but beyond this point it inclines backward and downward behind the medial condyle of the humerus. The *radial nerve* follows the brachial artery a short distance distal to the posterior axillary fold. Its further course is indicated by an oblique line descending outward across the posterior aspect of the arm, where it meets the lateral bicipital sulcus about 2.5 cm. below the deltoid insertion (Fig. 779). From this point the trunk of the radial nerve follows the lateral bicipital sulcus to the front of the lateral epicondyle of the humerus, where it divides into superficial and deep branches (p. 840).

The depression on the lateral aspect of the arm marking the *deltoid insertion* is a valuable landmark indicating the level at which the main nutrient artery enters the humerus and the radial nerve crosses the posterior surface of the bone. It also marks the level of the insertion of the coracobrachialis muscle into the medial aspect of the humerus.

The neurovascular relationships at the medial bicipital groove, at the back of the medial condyle of the humerus, along the distal part of the lateral bicipital groove, and at the posterior aspect of the arm just below the level of the deltoid insertion are contraindications to bold incision in these areas.

ENVELOPING (DEEP) FASCIA OF THE ARM AND THE INTERMUSCULAR SEPTA. The deep fascia furnishes a complete investment for the arm and is continuous with the deep fascia of the forearm. From the deep surface of this ensheathing layer are derived the lateral and medial intermuscular septa, strong, fibrous partitions extending from the ensheathing layer to the shaft and epicondylar ridges of the humerus and dividing the arm into anterior and posterior osseo-aponeurotic compartments. These compartments, in a measure, limit the extravasation of hemorrhage and the spread of infection. The *medial intermuscular septum* extends from the medial epicondyle to the insertion of the coracobrachialis muscle, and the *lateral intermuscular septum* extends from the lateral epicondyle to the deltoid insertion.

The *anterior (flexor) compartment* contains the coracobrachialis, biceps and brachialis (anticus) muscles, the brachial artery and veins, the basilic vein, and the median, musculocutaneous and median antebrachial cutaneous nerves (Figs. 773, 776). The *posterior (extensor) compartment* contains the triceps brachii muscle (Figs. 773, 779). Several structures are common to both compartments: the radial nerve, profunda (superior profunda) artery, ulnar nerve, superior ulnar collateral (inferior profunda) artery, and the inferior ulnar collateral (anastomotica magna) artery.

MUSCLES OF THE BRACHIAL COMPARTMENTS. The biceps brachii, coracobrachialis and brachialis (anticus) muscles occupy the anterior brachial or flexor compartment (Fig. 776). The *biceps muscle* (N. musculocutaneus, C 5, 6) occupies most of the compartment. It arises by a short head from the tip of the coracoid process and from a long head attached to the upper margin of the glenoid fossa, and inserts into the posterior part of the tuberosity of the radius (Fig. 777, *a*). Its tendon is separated from the anterior part of the tuberosity by a bursa. Its primary function is flexion and supination of the forearm, but it acts also as a suspensory mechanism for the humerus and aids in flexion and adduction of the arm at the shoulder. "It puts the corkscrew in and pulls the cork out." Its mesial border is the guide to

to the radial groove and from the medial intermuscular septum. The lateral head arises from all the surface of the humerus proximal to the groove and from the lateral intermuscular septum. The long head arises by a tendon from the inferior surface of the glenoid fossa. From these varied origins the fibers are inserted into the proximal surface of the olecranon.

BRACHIAL ARTERY, ITS BRANCHES AND COLLATERAL ANASTOMOSES. The BRACHIAL ARTERY, the continuation of the axillary artery, extends from the lower border of the teres major muscle to the antecubital fossa just distal to the skin crease at the bend of the elbow. Opposite the neck of the radius, it bifurcates into the radial and ulnar arteries (Fig. 780).

The *proximal third* of the brachial artery lies upon the medial aspect of the limb anterior to the long and medial heads of the triceps muscle, and may be compressed laterally against the humerus. In operative exposure the artery is found beneath the deep fascia, bordered laterally by the coracobrachialis muscle and partly separated from it by the median nerve. The medial (internal) cutaneous nerve of the forearm and the ulnar nerve separate it from the basilic vein.

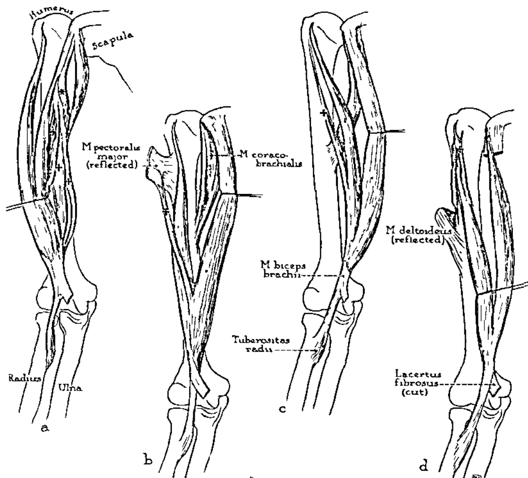


Fig. 778. VARIATIONS IN ORIGIN OF THE BICEPS BRACHII MUSCLE (CONTINUED).

a, A case with 3 accessory humeral heads of origin. The proximal cross covers 1 of 3 small and separate, but contiguous, slips of origin, the intermediate and distal crosses mark the 2 additional portions; an accessory band between the biceps brachii and coracobrachialis is indicated by asterisk. *b*, An accessory head arises from the deep surface of the tendon of insertion of the pectoralis major (cut end of the latter is reflected lateralward). This accessory head lies in the sulcus between the long and short heads, and terminates at their point of union. In *c*, an accessory long head takes origin from the lateral bicipital ridge proximal to the upper margin of the tendon of the pectoralis major. *d*, The long head of the muscle arises, not from the supraglenoid tubercle, but from the capsule of the shoulder joint and from the floor of the bicipital groove as far distalward as the inferior edge of the tendon of insertion of the pectoralis major. (From Greig, Budinger and Anson: Quart. Bull., Northwestern Univ. M. School, 26: 241–4, 1952.)

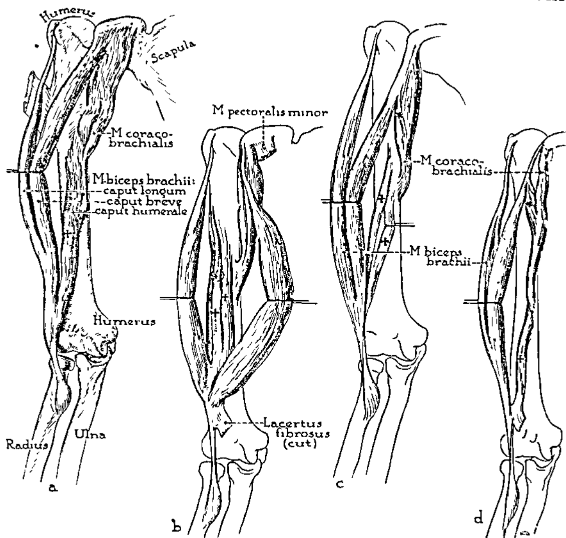


Fig. 777. VARIATIONS IN ORIGIN OF THE BICEPS BRACHII MUSCLE.

Each supernumerary humeral head is marked by a cross, an accessory band between the biceps brachii and the coracobrachialis is indicated by an asterisk.

a and *d*, Commonest type of variation, in which a single accessory head of origin (making the muscle tricipital) arises from the anteromedial aspect of the humerus proximal to the origin of the brachialis muscle and lateral to the insertion of the coracobrachialis. In *a*, the usual fusion occurs, while in *d*, a large share of the tendinous fibers pass into the lacertus fibrosus directly. In *d*, proximally, a band of fascicles passes from the biceps brachii to the coracobrachialis. *b* and *c*, A type of variation in which the humeral origin of the biceps brachii is represented by 2 contributions (to produce a quadricipital muscle) In *b*, the accessory slips fuse with the long head, while in *c*, the commoner arrangement, the additional slips join the short head; in *b*, one accessory portion (ringed) lies superficial to the other, whereas in *d*, they course side by side. (From Greig, Budinger and Anson: Quart Bull., Northwestern Univ. M. School, 26: 241-4, 1952.)

complete fusion of the heads; origin of a supernumerary head from the deltoideus, brachialis, brachioradialis, or pronator teres muscle.

From an origin in the coracoid process the *coracobrachialis muscle* (N. musculocutaneus, C 7) runs parallel to the short head of the biceps and inserts into the middle portion of the mesial margin of the humerus. It aids in flexion and adduction of the arm. The *brachialis (anticus) muscle* arises from the distal half of the anterior surface of the humerus and the adjacent intermuscular septum, and passes anterior to the elbow joint to insert into the coronoid process of the ulna. It is supplied by the musculocutaneous (C 5, 6) and radial nerves and is a powerful flexor of the elbow. In fracture of the shaft of the humerus a portion of the brachialis muscle may be interposed between the fragments and cause nonunion.

The posterior or extensor compartment compactly encloses the *triceps brachii muscle* (N. radial, C 6, 7, 8) (Fig. 779). The medial head of this muscle arises from all the posterior surface of the shaft of the humerus distal

recurrent artery (p. 865). The *inferior ulnar collateral* (*anastomotic*) *artery* arises from the brachial artery near the elbow and forms a rich anastomotic network on the mesial aspect of the elbow.

The branches of the brachial artery form COLLATERAL ANASTOMOSES about the elbow which connect the parent trunk with the arteries of the forearm. Communications are established between the profunda artery and the superior and inferior collateral arteries superiorly and the radial and ulnar recurrent arteries and dorsal interosseous recurrent artery inferiorly (Fig. 780).

When the brachial artery is ligated above the origin of the profunda artery, the blood flow in the limb is re-established through an anastomosis between the circumflex and axillary arteries proximally, and the ascending branches of the profunda artery distally. When the brachial artery is ligated below the level of the profunda artery and above the superior ulnar collateral artery, anastomotic connections are established between the profunda artery proximally and the radial recurrent, dorsal ulnar recurrent, and inferior ulnar collateral arteries, distally.

RADIAL, MUSCULOCUTANEOUS, MEDIAN AND ULNAR NERVES. Below the teres major muscle the *radial nerve* lies between the long head of the triceps muscle and the shaft of the humerus (Figs. 751, 779). After supplying the triceps muscle the nerve enters the radial groove with the profunda branch of the brachial artery and supplies the medial and lateral heads of the triceps muscle, between which it lies. In the radial groove the nerve passes distally and laterally across the back of the arm, where it traverses the lateral intermuscular septum and enters the anterior brachial compartment. The point at which the nerve pierces the septum may be located at the union of the proximal and middle thirds of a line joining the lateral epicondyle and the insertion of the deltoid muscle.

In the anterior compartment the radial nerve lies at the lateral margin of the brachialis muscle, and is overlaid proximally by the brachioradialis (supinator longus) muscle, and distally by the extensor carpi radialis longus

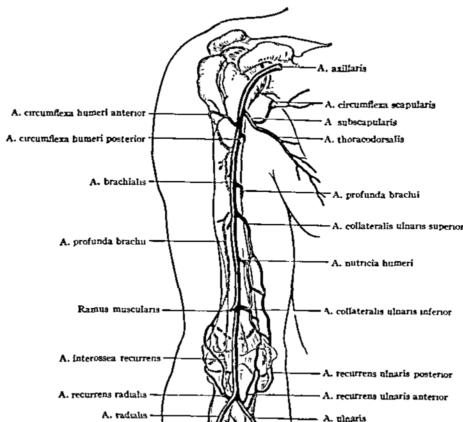


Fig. 780. BRACHIAL ARTERY AND ITS BRANCHES.

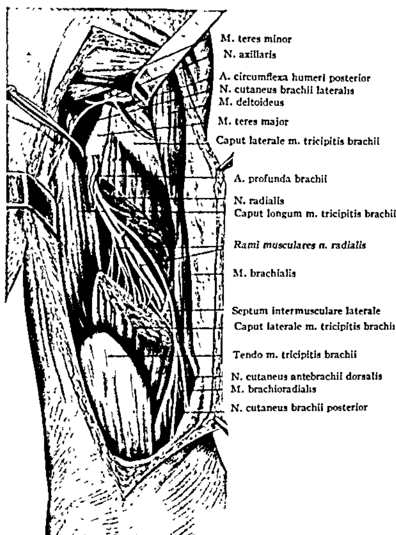


Fig. 779. DEEP DISSECTION OF THE POSTERIOR COMPARTMENT OF THE ARM.
Removal of a section from the lateral head of the triceps muscle shows the path of the radial nerve and the accompanying vessels.

The *middle third* of the artery inclines gradually forward and outward, and, in operative exposure, is found overlapped by the medial border of the biceps muscle; it is overlaid by the median nerve, which crosses it obliquely. The medial cutaneous nerve and the basilic vein are separated from the artery by the deep fascia. An incision carried too far toward the *medial aspect of the arm may expose the ulnar* nerve with the ulnar collateral (inferior profunda) artery where they diverge from the brachial artery to reach the medial intermuscular septum.

The *distal third* of the artery is overlapped by the medial border of the biceps muscle, but near its termination lies medial to the biceps tendon, overlaid by the lacertus fibrosus (bicipital fascia). Medial to it lies the median nerve (Fig. 788).

The brachial artery has several BRANCHES. The (*superior*) *profunda artery* arises from the posterior and inner aspect of the main trunk near its origin and passes backward. It is associated with the radial (musculospiral) nerve, which it accompanies in the radial groove to the front of the external condyle of the humerus, anastomosing there with the *radial recurrent artery* (Fig. 780). The principal *nutrient artery* of the humerus sometimes arises from the profunda in the radial sulcus, but usually has its origin in a muscle branch near the middle of the arm. It may be injured in fractures and delay union. The *superior ulnar collateral* (*inferior profunda*) *artery* arises near the middle of the arm and accompanies the ulnar nerve to the groove on the posterior surface of the medial epicondyle, where it anastomoses with the dorsal (anterior) ulnar

of the shaft is exposed through the interval between the triceps muscle and the deep surface of the medial intermuscular septum.

LATERAL APPROACHES TO THE STRUCTURES OF THE ARM. The lateral brachial routes consist of a lateral bicipital path for exposure of the radial nerve in the middle of the shaft and a lateral humeral path for exposure of the shaft of the humerus (Fig. 781).

The incision for the *lateral approach to the radial nerve* begins at the deltoid insertion and descends two fingerbreadths immediately anterior to the lateral intermuscular septum. It runs obliquely forward and downward toward the crease of the elbow. After incision of the deep fascia over the interval between the brachioradialis and brachialis muscles and separation of the muscles, the radial nerve is

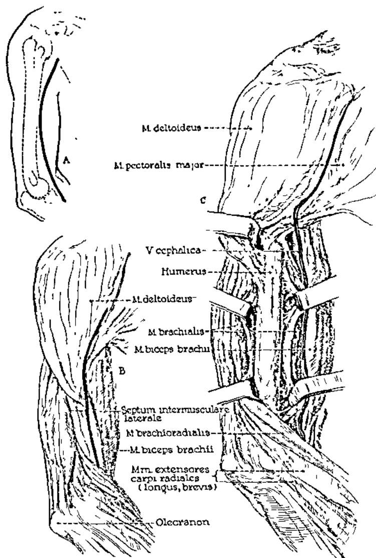


Fig. 781. ANTEROLATERAL APPROACH TO THE HUMERUS (THOMPSON AND HENRY).

This is the most commonly used approach to the shaft of the humerus. *A*, Portions of the incision shown are selected to meet the surgical situation. The cephalic vein, which is close by, just under the enveloping fascia, should be protected. *B*, To expose the *upper third of the humerus, the muscular cleavage line runs* between the medial border of the deltoid and the pectoralis major muscles. In the midportion the brachialis muscle covers the humerus anteriorly and is safely divided, as shown, because the radial nerve supplies the lateral third, and the median and musculocutaneous nerves supply the medial two thirds. *C*, The shaft of the humerus is exposed by subperiosteal dissection. Bone within 2 inches of the condyles can be reached. The radial nerve traverses the inner surface of the brachioradialis muscle at this level, and it is wise to identify the nerve and retract it gently with the muscle. Upward, the incision may be extended, as in the anteromedial approach to the shoulder joint (Fig. 761).

muscle. Anterior to the lateral epicondyle, the radial nerve divides into superficial (radial) and deep (posterior interosseous) nerves.

The radial nerve may be involved in fractures of the shaft of the humerus, either between the fragments themselves or in the callus deposited by the fracture, and may necessitate operative intervention. The nerve may be located in the anterior compartment of the arm in the interval between the brachioradialis and the brachialis muscles (Fig. 788). Because of the absence of a definite demarcation between these muscles, the interval separating them is not easy to determine. If the cleft between the brachialis and biceps muscles is opened inadvertently, the musculocutaneous nerve is exposed and may be mistaken for the radial nerve. The radial nerve can be identified where it pierces the lateral intermuscular septum, and may be traced upward by cutting through the musculotendinous roof of the radial groove.

The *musculocutaneous nerve*, upon deviating from the axillary artery, supplies and then pierces the coracobrachialis muscle (Fig. 750). It then runs distally between the biceps and brachialis muscles, supplying both, and emerges at the elbow along the lateral margin of the biceps tendon.

The *median nerve* runs along the medial bicipital furrow in close relationship with the brachial artery (Figs. 750, 776). At first it lies lateral to the artery; then, at the middle of the arm, it crosses over, or occasionally under, the artery and descends along the mesial side to the elbow.

In the proximal half of the arm the *ulnar nerve* lies medial to the brachial artery and anterior to the triceps muscle (Fig. 776). In the distal half of the arm it deviates from the brachial artery and passes behind the medial intermuscular septum. It passes into the elbow region between the medial epicondyle of the humerus and the olecranon.

SHAFT OF THE HUMERUS. The shaft of the humerus consists of a central medullary canal and a thick, dense cortex. Near the middle of the inner border of the shaft is an opening for the principal *nutrient canal*, which is directed obliquely downward for a long course through the cortex before opening into the medullary cavity. Occasionally the nutrient foramen lies in the radial groove. The rough eminence at the center of the medial aspect of the shaft is marked by the *radial sulcus*, which descends obliquely downward and outward, curving around the bone until it reaches the lateral margin of the humerus about 2.5 cm. below the deltoid eminence. In its middle the shaft of the bone is prismatic; distally it is flattened anteroposteriorly and curves slightly forward. The medial and lateral margins of the distal part of the shaft, especially the lateral margin, are strong and form stout supporting columns, *supracondylar ridges*, continued directly into the epicondyles. The lateral intermuscular septum is attached to the lateral ridge, and the medial intermuscular septum to the medial ridge.

The *relations* between the humerus and the muscles differ above and below the level of the deltoid insertion. In the upper or deltoid segment much of the shaft is devoid of muscle attachment; because of this, the deltoid, biceps and coracobrachialis muscles and the long head of the triceps muscle retract freely when divided. In the lower or subdeltoid segment the muscles invest and are attached to the humerus, so that excessive retraction of the divided muscles is prevented. Since the biceps muscle has no point of direct attachment to the humerus, save where the capsular and synovial expansions bind the tendon of the long head to the intertubercular sulcus, there is a wide interval of separation when the tendon is severed

Surgical Considerations

MEDIAL APPROACHES TO THE STRUCTURES OF THE ARM. The *medial vasculoneural approach* follows the medial bicipital sulcus and affords surgical access to the brachial vessels and median nerve. It extends along a line connecting the apex of the axilla with the medial septum. In exposure of the ulnar nerve in the upper third of the arm, an incision over the medial bicipital groove exposes the nerve mesial to the brachial vessels. In the middle third of the arm the nerve lies at the level of, or just behind, the origin of the medial intermuscular septum. In the lower third of the arm the ulnar nerve lies directly behind the medial intermuscular septum (Fig. 790).

In the upper and middle thirds of the arm *access to the shaft of the humerus* is gained by retracting the medial head of the triceps muscle backward, after separating it from the medial intermuscular septum. The lower third

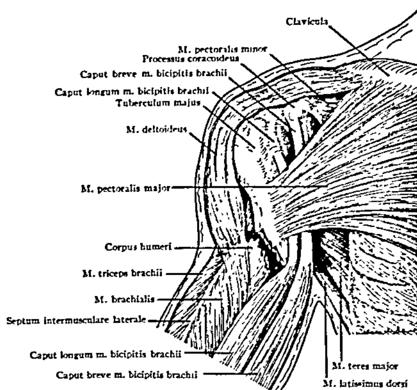


Fig. 783. FRACTURE OF THE SHAFT OF THE HUMERUS BETWEEN THE DELTOID INSERTION AND THE INSERTIONS OF THE AXILLARY FOLD MUSCLES.

The proximal fragment is drawn medially by the pectoralis major, the latissimus dorsi and teres major muscles. The distal fragment is drawn upward by the deltoid, coracobrachialis, biceps and triceps muscles, and outward by the deltoid muscle.

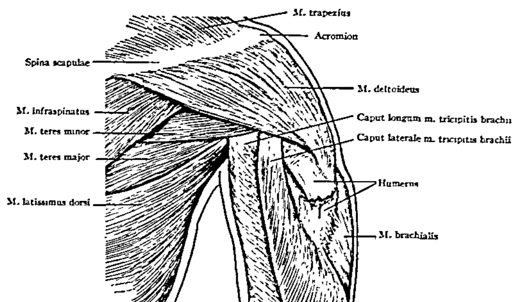


Fig. 784. FRACTURE OF THE HUMERUS JUST DISTAL TO THE DELTOID INSERTION.

The deltoid muscle tilts the distal end of the proximal fragment outward.

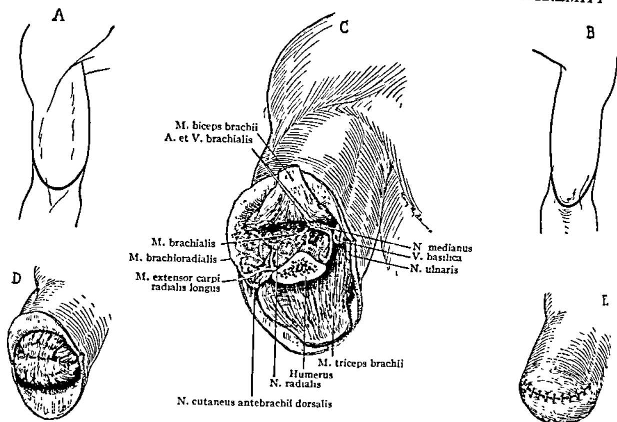


Fig. 782. AMPUTATION THROUGH THE LOWER THIRD OF THE ARM.

exposed on a level with the superior fibers of the brachioradialis muscle and is traced upward. When it is necessary to follow the nerve into the radial sulcus, the lateral intermuscular septum is exposed further, and the dissection is carried backward through the entire thickness of the triceps muscle. This approach, combined with the retrodeltoid approach, gives adequate exposure to the radial nerve in its humeral course.

The *anterolateral approach* to the shaft of the humerus mainly follows the lateral intermuscular septum from the anterior border of the deltoid muscle to the external epicondyle of the humerus (Fig. 781). It is the main access to the shaft of the humerus and is used for open reduction of fractures, surgical treatment of osteomyelitis, and excision of malignant and benign bone tumors.

RETRODELTOID APPROACH TO THE PROXIMAL PART OF THE HUMERUS. The incision in the retrodeltoid approach to the proximal part of the humerus is made parallel to the posterior border of the deltoid muscle about a thumb-breadth mesial to it, and extends to the margin of the humerus at the attachment of the lateral intermuscular septum (*cf.* Fig. 781). Lateral retraction of the deltoid muscle exposes the longitudinal fibers of the long head of the triceps muscle and the external axillary (quadrilateral) space (p. 799). Through this space the axillary nerve and the posterior circumflex vessels pass backward in close relationship with the surgical neck of the humerus. In the interval between the origin of the lateral head of the triceps muscle and the deltoid insertion the humerus is devoid of muscle attachments and permits direct surgical access.

POSTERIOR BRACHIAL APPROACH TO THE RADIAL NERVE. The posterior brachial approach gives direct access to the radial nerve as it leaves the axilla. The incision begins at the middle of the posterior border of the deltoid muscle and continues downward toward the olecranon. After incision of the deep fascia the space between the long and lateral heads of the triceps muscle is sought by blunt dissection. Through this space the radial nerve and the profunda artery emerge from the axilla and run in the radial groove. By division of the lateral head of the triceps muscle the nerve may be followed throughout the groove and along the lateral intermuscular septum to the lateral region of the arm (Fig. 779).

AMPUTATION THROUGH THE ARM. In *amputation through the lower third* of the arm,

of the shaft. In the resulting displacement the distal fragment is drawn up behind the proximal fragment by the triceps muscle. The distal end of the proximal fragment may project forward above the level of the crease of the elbow, penetrate the brachialis muscle, and may even injure the brachial artery.

Fracture by muscle action is more common in the shaft of the humerus than in the shaft of any other bone. As a rule, it results from a forcible effort in throwing, and occurs most frequently just below the deltoid insertion. The contraction of the deltoid muscle arrests the bone suddenly, and the impetus acquired by the lower end of the humerus produces the fracture.

Treatment of fractures of the shaft of the humerus, whether they be simple or comminuted, is best carried out by means of the hanging cast previously mentioned in the treatment of fractures about the surgical neck of the humerus. The same type of cast and the same postcast care should be followed. Unless the fracture is an open one, the hanging cast should certainly be tried before any attempt at open reduction and any form of internal fixation. If the fracture, however, is an open fracture which needs débridement of the fracture site, or if there is proved to be muscle interposition which prevents the approximation of the fractured ends, then internal fixation can be accomplished and the use of the intra-

Fig. 786. RUPTURE AND REPAIR OF THE TENDON OF THE LONG HEAD OF THE BICEPS MUSCLE.

A, Condition at operation, which shows the tendon of the long head of the biceps completely torn from the cartilaginous lip of the glenoid fossa and turned over on itself in a jack-knife fashion; *B*, the tendon sutured to the coracoid process and to the short head of the biceps. (From E. L. Gilcreest: J A.M.A.)

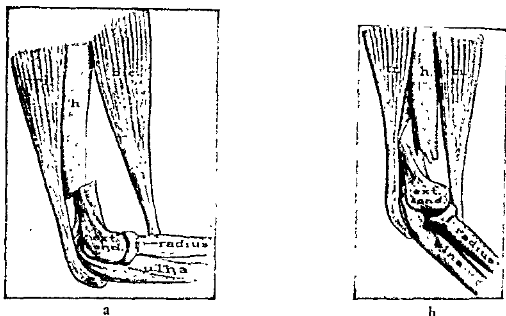


Fig. 785. FRACTURES OF THE LOWER THIRD OF THE SHAFT OF THE HUMERUS.

a, Flexion fracture. *b*, Extension fracture.

equal anterior and posterior rounded flaps are fashioned (Fig. 782). If the saw line is made through the condyles, the biceps, brachialis and triceps muscles are cut from their insertions and are allowed to retract to the saw line. The forearm muscles arising from the supracondylar ridges are cut to retract to the saw line. The biceps tendon is sutured to the brachialis (anticus) muscle, which is brought over the end of the bone and sutured to the triceps muscle. If the supracondylar saw line is selected, the muscle and fascial flaps are cut higher up, the biceps and brachialis muscles are sectioned to retract to the saw line, and the triceps muscle is divided at its insertion into the olecranon process. The triceps muscle is brought forward over the humerus and sutured into the brachialis and biceps muscles.

In *amputation above the lower third* of the arm all bone should be saved to give as much leverage as possible for an artificial limb. Equal anterior and posterior flaps of skin and fascia are used, and a thin muscle flap is cut from the posterior or the anterior brachial muscles (preferably the triceps muscle) and is carried across the end of the bone. The biceps muscle retracts considerably more than the brachialis and triceps muscles because it has no humeral attachment. When the saw line is above the deltoid insertion, the power of abduction is lost unless the deltoid muscle is fixed to the stump end.

FRACTURES OF THE SHAFT OF THE HUMERUS. Fractures in the shaft of the humerus occur in those parts of the bone least protected by muscles (Figs. 783 to 785). Reference is made to the common sites of fracture because of the displacement of the fragments caused by muscle pull, although the important factor in determining the displacement of fragments is not so much the muscle action as the force which causes the fracture. Displacement is favored by obliquity of the fracture line.

With a fracture line *between the insertions of the axillary muscles and the deltoid insertion*, the distal end of the proximal fragment is drawn mesially by the axillary muscles (Fig. 783). The distal fragment is pulled upward by the deltoid, coracobrachialis, biceps and triceps muscles and outward by the deltoid muscle. In fracture *distal to the deltoid insertion* (near the center of the shaft) the tendency for the muscles to cause displacement is not so marked, but the deltoid muscle tends to tilt the distal end of the proximal fragment outward (Fig. 784). The distal fragment may be drawn proximally and mesially by the pull of the biceps and triceps muscles acting through their insertions at the elbow. The upward pull is overcome partly by gravity if the elbow is not supported.

Fracture of the humerus *near the articular end* (*supracondylar fracture*) usually is transverse or somewhat oblique to the long axis

CHAPTER 29

Elbow

The elbow is divided into three regions: anterior or vasculoneuromuscular, posterior or olecranon, and bones and joints.

Anterior or Vasculoneuromuscular Region

The anterior or vasculoneuromuscular region includes the soft parts anterior to the plane of the elbow joint over an area three fingerbreadths proximal and distal to the joint.

SURFACE ANATOMY AND MUSCLE LANDMARKS. When the forearm is supinated and extended fully, the anterior aspect of the elbow presents three muscular projections. The *median muscular projection* is made by the lower extremity of the tapering biceps

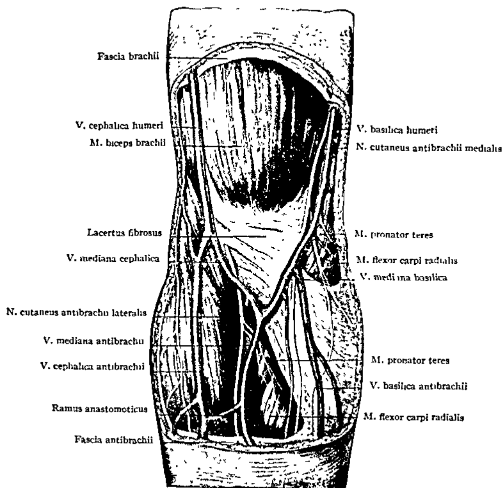


Fig. 787. SUPERFICIAL STRUCTURES IN THE ANTERIOR REGION OF THE RIGHT ELBOW. The brachial and antebrachial fascia have been removed, but the superficial veins are *in situ*.

medullary Rush type of pin inserted from the proximal end of the humerus in the region of the greater tuberosity. After internal fixation the use of a hanging cast as described before is the treatment of choice. In such an open reduction, even in the primary operation, multiple chip grafts of bone taken from the cortex above and below the fracture site and additional bone if it is available should be packed about the fracture site to give this fracture every opportunity possible to bony union. Failure of union following open reduction of the shaft of the humerus is common. Union, however, of a closed fracture of the shaft of the humerus with a hanging cast is uncommon.

Failure of the broken fragments to unite, *pseudoarthrosis*, is observed frequently. The presence of muscle tissue between the fragments, lack of muscle attachment, inadequate blood supply, and the difficulty of immobilization are important etiologic factors. Injury to the nutrient artery where it enters the bone near the middle of the shaft may injure the blood supply to the humerus and favor nonunion.

The most frequent *complication* is paralysis of the extensor muscles of the forearm and "wrist drop" following damage to the radial nerve. The close proximity of the nerve to the bone in the radial groove renders it prone to injury in displacement of the fragments, or later by compression from the callus formed at the site of fracture. Injury to the brachial artery is rare, but the vessel may be stretched by the displaced fragment so as to occlude its lumen; thrombosis may occur from excessive bruising of its coats; or it may be perforated by a fragment of bone.

RUPTURE OF THE BICEPS MUSCLE AND TENDON. Rupture may occur in the substance of the biceps muscle at the junction of the muscle and its tendon, in the tendons, or at the origin or insertion of the tendons (Fig. 786). A muscle which has degenerated from any debilitating process is prone to rupture; a normal muscle may give way under violent strain. Sharp pain in the shoulder, arm or elbow may or may not be felt. Progressive weakness in the use of the arm usually is noted. If the rupture occurs in the proximal portion of the biceps muscle, a swelling appears in the distal part of the arm; if it occurs in the distal portion, the swelling is proximal. Because of the rich blood supply to the muscle, partial or complete tears produce considerable bleeding and subsequent hematoma formation. Extensive rupture necessitates repair. If the tendon of the long head of the muscle is torn from its attachment to the lip of the scapular glenoid, the tendon should be sutured both to the short head of the biceps muscle and to the coracoid process.

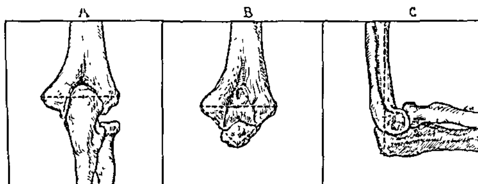


Fig. 789. RELATIONS OF THE BONY PROMINENCES OF THE ELBOW IN FLEXION AND EXTENSION.

The 3 points mark a straight line in extension and a triangle in right-angle flexion. Side view and right-angle flexion show these points to lie in a plane parallel with the posterior surface of the humerus.

M. triceps brachii
N. ulnaris et A. collateralis ulnaris superior
Epicondylus medialis humeri
Rete articulare cubiti
Olecranon
M. anconaeus
Margo dorsalis ulnae
A. interossea recurrens
M. flexor carpi ulnaris
M. extensor pollicis longus
M. extensor indicis proprius
M. extensor carpi ulnaris
M. brachialis
A. collateralis radialis
M. brachioradialis
N. cutaneus antibrachii dorsalis
M. extensor carpi radialis longus
Epicondylus lateralis humeri
Capitulum radii
Ramus profundus n. radialis
M. supinator
A. interossea dorsalis
M. extensor carpi radialis brevis
Corpus radii
M. abductor pollicis longus
M. extensor pollicis brevis
M. extensor digitorum communis

Fig. 790. VASCULONEURAL AND MUSCULAR STRUCTURES IN THE POSTERIOR REGION OF THE RIGHT ELBOW.

Fig. 788. DEEP VASCULONEURAL STRUCTURES IN THE ANTERIOR REGION OF THE RIGHT ELBOW. The brachial and antebrachial fasciae and the lacertus fibrosus have been removed. The muscular lateral walls of the cubital fossa are retracted.

muscle on the subjacent brachialis muscle. The biceps is condensed into a narrow tendon which dips into the antecubital fossa and inserts into the posterior part of the radial tuberosity. The brachialis muscle is attached directly to the underlying humerus and inserts by a short, thick tendon into the coronoid process of the ulna. The median biceps bulge is set apart from the muscular projections which flank it by grooves which are the lower extremities of the bicipital sulci. By the coalescence of the sulci a V-shaped figure is formed which is continued downward into the shallow median furrow on the anterior surface of the forearm. The *medial muscular projection* corresponds to the pronator teres, flexor carpi radialis and palmaris longus muscles. The *lateral muscular projection* consists of the brachioradialis (supinator longus) and the radial extensor muscles (Figs. 787, 788).

These masses of muscle bound the *antecubital fossa*, a triangular depression distal to the intercondylar line. The finger may be inserted easily into the depression between the biceps tendon and the brachioradialis muscle. Medial to the tendon, the sharp upper margin of the *lacertus fibrosus* can be felt as a membranous septum extending over the hollow of the cubital fossa and blending with the deep fascia of the medial aspect of the forearm (Fig. 787). This septum prevents examination between the biceps tendon and the pronator teres muscle. The pulsations of the brachial artery are felt by inserting the finger beneath the proximal margin of the septum.

The *joint line* anteriorly is not easily recognized because of its obliquity and the amount of overlying muscle. It is represented fairly accurately by a line crossing the elbow from a point about 1 cm. below the external epicon-

Mesial rotation (pronation) of the forearm by the pronator teres muscle carries the nerve away from the radiohumeral joint and lessens the danger from operative injury.

Medial and Lateral Bicipital Approaches to the Structures about the Elbow. In the *medial bicipital approach* the median basilic and basilic veins are retracted and ligated, and the free upper margin of the lacertus fibrosus is incised. Retraction of the edges of this fascia carries the biceps muscle laterally and the pronator teres muscle mesially. This path affords surgical access to the brachial artery and its bifurcation, and to the median nerve lying mesial to it. The nerve can be traced between the two heads of the pronator teres muscle by resection and mesial retraction of the head of the pronator teres, which is attached to the coronoid process of the ulna. A deep abscess may be evacuated through this incision.

In the *lateral bicipital approach* the interval between the brachioradialis muscle and biceps

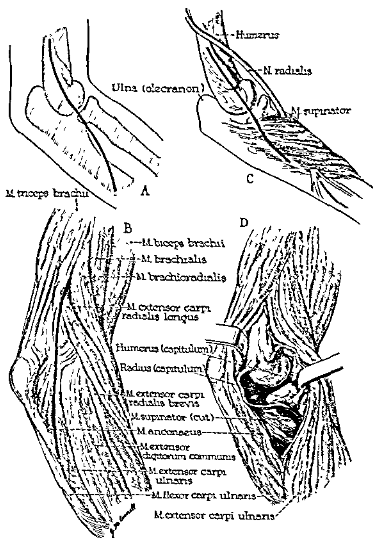


Fig. 792. LATERAL APPROACH TO THE ELBOW JOINT.

A, The incision begins on the lateral supracondyloid ridge 5 to 7 cm. above the joint, and extends down over the head of the radius. If more room is needed, the lower end of the incision is swung backward to permit approach between the anconeus and the extensor muscles. *B*, Line of deeper development. *C*, Location of radial nerve in relation to incision. *D*, Muscles stripped subperiosteally from the lower end of the humerus, and retracted. Below, the anconeus is separated and retracted from the extensor carpi ulnaris muscle. The joint capsule is then incised longitudinally. For further exposure, the supinator muscle may be retracted. If it is necessary to incise the supinator, great care should be taken not to injure the radial nerve, which traverses the belly of the muscle. If the entire muscle must be reflected for proper exposure, it should be incised close to the ulna, as in *C*, and retracted anteriorly.

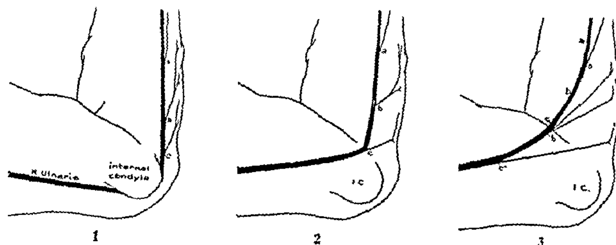


Fig. 791. REROUTING THE ULNAR NERVE TO THE FRONT OF THE ELBOW.

Illustrating the greater length of slack to be obtained by splitting the sheath of the nerve and stripping back the muscular branches; this enables the nerve to assume a more anterior position at the elbow. 1, Ulnar nerve at the elbow with muscle branches, *a*, *b*, *c*. 2, Ulnar nerve dislocated in front of the medial condyle; the transplantation is restricted by the binding effect of branches *b* and *c*. 3, The sheath of the ulnar nerve has been split, permitting the branches *b* and *c* to leave the nerve at a higher level and the nerve to be dislocated in front of the elbow, thus gaining several additional centimeters of slack. (From Babcock: Textbook of Surgery.)

dyle to a point about 2.5 cm. below the internal epicondyle.

CUBITAL (ANTECUBITAL) FOSSA AND CONTENTS. The cubital fossa is a triangular depression anterior to the elbow (Figs. 787, 788). Its base is an imaginary line connecting the humeral condyles, and its sides are the converging borders of the pronator teres and brachioradialis muscles. After reflecting the superficial veins and deep fascia the *brachial artery* and venae comites are exposed at the mesial side of the biceps tendon. The *median nerve* lies a short distance mesial to the brachial artery. These structures are surrounded by a quantity of areolo-adipose tissue, continuous above with the connective tissue planes of the arm. The floor of the space is the brachialis (anticus) muscle. Within the muscular interval at the lateral aspect of the biceps tendon the *radial nerve* divides into its terminal branches (Fig. 788).

VESSELS AND NERVES. The *brachial artery* enters the region in the medial bicipital groove, where it lies on the brachialis muscle (Fig. 788). It traverses the cubital fossa under the lacertus fibrosus and divides into the radial and ulnar arteries at the level of the coronoid process of the ulna and the neck of the radius. The *radial artery* continues in the direction of the brachial trunk and runs along the border of the pronator teres muscle to the brachioradialis muscle, the mesial border of which it follows through the forearm into the wrist. At the elbow the radial artery gives off the radial recurrent artery. The *ulnar artery* is the larger terminal branch, but the less direct continuation, of the brachial artery. It runs in the forearm deep to the muscles arising from the mesial epicondyle. About the elbow it gives off the posterior ulnar recurrent, the anterior ulnar recurrent and the common interosseous arteries. The collateral anastomoses following ligation of the brachial artery have been described (p. 829).

The *median nerve* enters the region in the medial bicipital groove, mesial to the brachial artery (Fig. 788). It passes into the forearm between the two heads of the pronator teres muscle and is separated from the ulnar artery by the deep head of that muscle. At the elbow it gives off a branch to the pronator teres, flexor carpi radialis, palmaris longus and flexor digitorium sublimis muscles. The results of injury to the median nerve are characteristic (p. 920). Under cover of the brachioradialis muscle at the level of the external humeral condyle, the *radial nerve* divides into superficial (radial) and deep (posterior interosseous) branches. The superficial branch is entirely sensory, and descends in the forearm deep to the brachioradialis muscle (Fig. 788). The deep branch crosses the joint line and is directed downward and backward into the supinator (brevis) muscle in close relation with the head of the radius (Fig. 790), where it is subject to trauma in fracture or in operative exposure of the lateral aspect of the elbow joint.

Mesial rotation (pronation) of the forearm by the pronator teres muscle carries the nerve away from the radiohumeral joint and lessens the danger from operative injury.

Medial and Lateral Bicipital Approaches to the Structures about the Elbow. In the *medial bicipital approach* the median basilic and basilic veins are retracted and ligated, and the free upper margin of the lacertus fibrosus is incised. Retraction of the edges of this fascia carries the biceps muscle laterally and the pronator teres muscle mesially. This path affords surgical access to the brachial artery and its bifurcation, and to the median nerve lying mesial to it. The nerve can be traced between the two heads of the pronator teres muscle by resection and mesial retraction of the head of the pronator teres, which is attached to the coronoid process of the ulna. A deep abscess may be evacuated through this incision.

In the *lateral bicipital approach* the interval between the brachioradialis muscle and biceps

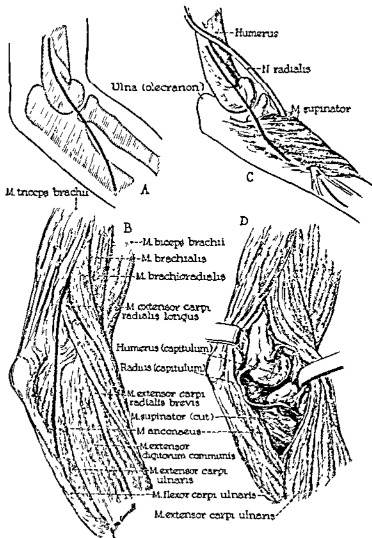


Fig. 792. LATERAL APPROACH TO THE ELBOW JOINT.

A, The incision begins on the lateral supracondyloid ridge 5 to 7 cm. above the joint, and extends down over the head of the radius. If more room is needed, the lower end of the incision is swung backward to permit approach between the anconeus and the extensor muscles *B*, Line of deeper development. *C*, Location of radial nerve in relation to incision. *D*, Muscles stripped subperiosteally from the lower end of the humerus, and retracted. Below, the anconeus is separated and retracted from the extensor carpi ulnaris muscle. The joint capsule is then incised longitudinally. For further exposure, the supinator muscle may be retracted. If it is necessary to incise the supinator, great care should be taken not to injure the radial nerve, which traverses the belly of the muscle. If the entire muscle must be reflected for proper exposure, it should be incised close to the ulna, as in *C*, and retracted anteriorly.

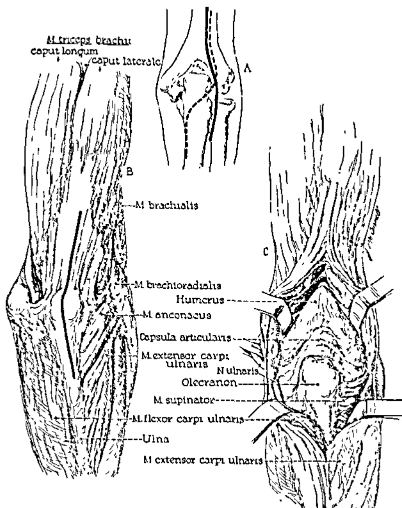


Fig. 793. POSTEROLATERAL APPROACH TO THE ELBOW JOINT.

A, Slightly curved incision begun 4 inches above the joint on the lateral aspect of the humerus, and extended downward just lateral to the olecranon for 3 inches. The more curved incision of the dotted line has less tendency for postoperative contracture. The distal portion should not lie directly over the posterior ulnar crest. *B*, The deep incision runs midline through the triceps tendon and the posterior border of the olecranon. *C*, The ulnar nerve exposed and carefully retracted. The triceps tendon is divided longitudinally and the soft parts reflected subperiosteally from the posterior part of the humerus and ulna. Complete exposure of the posterior aspect of the joint is obtained.

tendon is exposed. Lateral retraction of the brachioradialis muscle exposes the recurrent radial artery and the radial nerve with its bifurcation into superficial and deep branches. The lateral condyle of the humerus, the joint line, and the head and neck of the radius also may be exposed.

Posterior or Olecranon Region

The posterior or olecranon region embraces the posterior soft parts of the elbow and affords easy access to the elbow joint and to the ulnar nerve. The joint coverings are thin, and the articular extremities of the bones are superficial.

SURFACE LANDMARKS. A knowledge of the normal relations of the bony prominences of the region is indispensable to correct diagnosis of the dislocations and fractures occurring in it (Fig. 789). Both epicondyles of the humerus are subcutaneous and readily palpable, but the *medial epicondyle* is the more prominent. A narrow, but rather deep, medial paraolecranon groove separates the epicondyle from the olecranon. The ulnar nerve usually can be felt as a cord on the posterior aspect of this groove. The *lateral epicondyle* is palpated most easily with the arm in semiflexion; with the arm in full extension the condyle is hidden in a small depression bounded by the anconeus muscle mesially and the radial extensor muscles laterally. The lateral epicondyle lies farther from the olecranon than does the medial epicondyle. The surface of the intervening lateral paraolecranon groove is comparatively flat. The

joint capsule and synovia are nearest the surface in the paraolecranon grooves. In joint effusions or with excessive synovial thickening the olecranon no longer is prominent, but lies in the depth of a shallow depression in the swollen tissues.

When the forearm is extended, the *intercondylar line* is horizontal and passes through the proximal border of the *olecranon* (Fig. 789). When the forearm is flexed, the olecranon gradually becomes prominent and sinks below the horizontal level of the intercondylar line. In right-angle flexion of the forearm it lies on the same plane as the posterior surface of the shaft of the humerus and represents the apex of an inverted equilateral triangle, the base angles of which are located at the epicondyles of the humerus. In full flexion of the forearm the olecranon tip is carried farther downward and lies anterior to the articular end of the humerus; the triceps tendon can be traced down to it.

Immediately distal to the lateral epicondyle and the depression marking the humeroradial

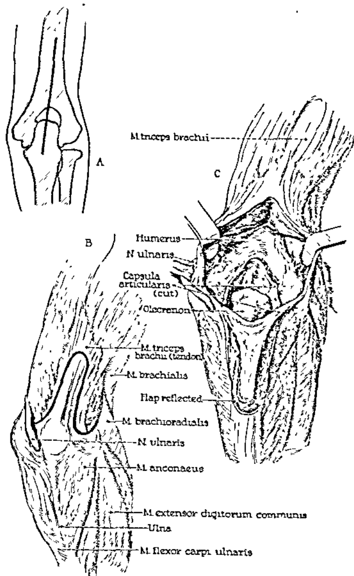


Fig. 794. POSTERIOR APPROACH TO THE ELBOW JOINT (CAMPBELL AND VAN GORDON).

A, Five-inch posterior midline incision over the lower humerus and tip of the olecranon. *B*, The soft tissues are widely retracted to expose the lower portion of the triceps muscle and tendon. The ulnar nerve is exposed. The 4-inch long, tongue-like incision of the triceps is cut in a shelving fashion of only fascia at the apex, muscle and fascia at the midportion, and full thickness of the triceps muscle and tendon at the broad base. *C*, The long tongue has been turned down. A longitudinal incision through the remainder of the triceps muscle to the bone permits subperiosteal reflection and exposure of the posterior lower end of the humerus and joint.

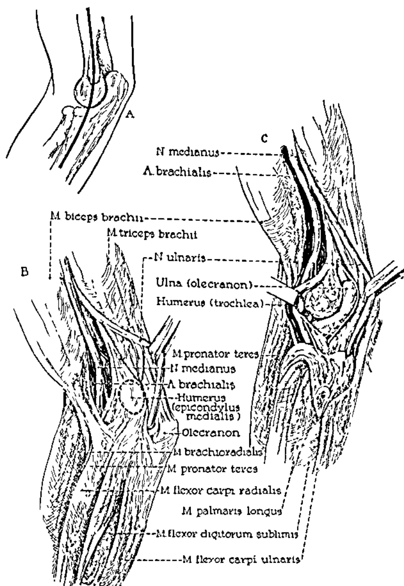


Fig. 795. MEDIAL APPROACH TO THE ELBOW JOINT (CAMPBELL AND MOLESWORTH).

A, With the elbow flexed, a curved incision is made over the medial epicondyle from 2 inches above to 2 inches below the joint. *B*, The ulnar nerve is located in the groove posterior to the condyle, carefully freed, and retracted posteriorly. *C*, The soft tissues about the upper half of the epicondyle are incised, and its tip is then separated with an osteotome and turned down with the attached common tendinous origin of the flexor muscles of the forearm. Care is needed to avoid injury to the small branches of the median nerve shown running to these muscles. The joint capsule is then incised and its edges retracted. Relatively adequate exposure of the joint surfaces can then be obtained by retraction and manipulation of the forearm.

joint is the projecting *head of the radius*, the rotary movements of which are detected readily by pronating and supinating the forearm alternately. When the forearm is flexed, the head of the radius lies 2.5 cm. anterior to the lateral epicondyle, the interval separating them being occupied by the capitulum of the humerus. When the forearm is in complete extension, a finger may be inserted into the distinct depression immediately proximal to the head of the radius; this depression corresponds to the lateral and posterior parts of the radiohumeral joint. A joint effusion obliterates the depression.

SUPERFICIAL STRUCTURES. The skin over the back of the elbow is thicker than that over the front and, because of an excessively loose subcutaneous tissue, moves with great freedom over the subjacent parts. The *olecranon bursa* lies between the dorsal surface of the olecranon process, the tendinous expansion of the triceps muscle, and the skin (Fig. 798). It is exposed to injury and infection from falls upon the elbow and abrasions of the skin.

POSTERIOR MUSCLES ABOUT THE ELBOW. Proximal to the joint line is the expansive tendon of the *triceps brachii muscle*, which inserts into the summit, margins and posterior surface of the olecranon (Fig. 790). Of the extensor group of muscles arising from the lateral epicondyle and the epicondylar ridge, the anconeus is the only muscle which belongs properly in the region. The *anconeus muscle* throughout its extent lies in the posterior region of the elbow and is palpable in the lateral olecranon groove. From its origin on the lateral epicondyle it spreads out to insert over the lateral surface of the olecranon and the posterior border of the ulna (Fig. 790); it covers the posterior aspects of the radiohumeral joint. The *flexor carpi ulnaris muscle* (p. 861) arises from the medial epicondyle and the medial surface of the olecranon.

VESSELS AND NERVES. The *arteries* at the back of the elbow are part of a periarticular network, made up of the collateral branches of the brachial, radial and ulnar trunks, which serves as a collateral anastomosis in obstruction or ligation of the brachial trunk (Fig. 790).

The *ulnar nerve* reaches the elbow behind the medial intermuscular septum and can be palpated as a round cord in the medial olecranon groove (Fig. 790). It lies in contact with the periosteum under the deep fascia of the arm and under an expansion of the triceps tendon which fuses mesially with the deep fascia of the forearm. The nerve leaves the para-olecranon region between the heads of origin of the flexor carpi ulnaris muscle, and may be injured in any trauma to the medial epicondyle or to the attachments of the flexor carpi ulnaris muscle. The nerve may be drawn from its bed and brought forward around the medial epicondyle to a more protected position on the anterior surface of the elbow (Fig. 791). This maneuver affords greater length to the nerve, a point of practical importance in ulnar nerve grafts.

Surgical Considerations

LATERAL APPROACH TO THE ELBOW JOINT. This incision, advised by Kocher (Fig. 792), is the most useful approach for exposure of the lateral compartment of the elbow and for fractures of the capitellum and the lateral humeral condyle.

POSTERIOR APPROACH TO THE ELBOW JOINT. Both incisions described (Figs. 793, 794) for posterior exposure of the elbow joint give completely adequate access to the humeral condyles and to the joint. The disadvantage of the tongue incision, which is commonly used for fusion of the joint, is the postoperative immobilization required for healing of the triceps tendon. The triceps-splitting incision permits earlier active motion and is preferred for arthrotomies and arthroplasties.

MEDIAL APPROACH TO THE ELBOW JOINT. Campbell and Molesworth advise removing the medial epicondyle of the humerus to expose the elbow joint (Fig. 795). The incision was first developed for fractures of the medial humeral epicondyle, but it was soon apparent that the radius and ulna could be manipulated to allow inspection of all portions of the joint. The close positions of the median and ulnar nerves (Figs. 788, 790) must be always in mind for their protection. This incision, but without the removal and replacement of the medial epicondyle, is commonly used for transposition of the ulnar nerve.

Bones and Joints

The distal extremity of the humerus, the proximal extremity of the ulna, and the head of the radius form the elbow joint and the proximal radio-ulnar joint. The elbow is a perfect hinge joint and depends for its stability upon the shape of the articular surfaces. These surfaces are disposed in such fashion as to render their mutual displacement difficult. The joint between the humerus and ulna is shaped so as to allow flexion and extension only; that between the humerus and the head of the radius is a ball-and-socket joint, allowing pronation and supination through rotary movement of the radius.

ARTICULAR EXTREMITIES. The DISTAL EXTREMITY OF THE HUMERUS is flattened anteroposteriorly into the widest part of the bone. At its junction with the shaft this portion bends forward until its plane is angulated 45 degrees on the shaft. It consists of the *trochlea* and *capitulum* (*capitellum*) for articulation with the semilunar notch (greater sigmoid cavity) of the ulna and the proximal surface of the head of the radius, respectively. The articular portion is bounded laterally by the epicondyles. The *medial epicondyle* is the longer and more prominent; its superior margin is about 2.5 cm. from the inner border of the trochlea. This greater length produces the

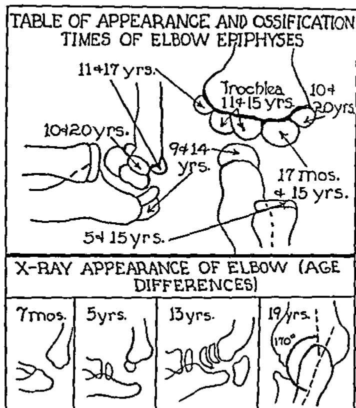


Fig. 796. TABLE OF APPEARANCE AND OSSIFICATION TIMES OF ELBOW EPIPHYSES. (Modified from Camp and Cilley: Am. J. Roentgenol.)

lateral deflection of the forearm known as the "carrying angle." The *lateral epicondyle* forms a conical projection immediately adjoining the capitulum. Each epicondyle may be traced proximally into an *epicondylar ridge*.

At the junction of the articular extremity with the shaft the humerus is hollowed out posteriorly into one fossa and anteriorly into two fossae. The anterior or *coronoid* and the *radial fossae* are occupied by fatty tissue covered by joint synovia. In full flexion the coronoid process of the ulna and the head of the radius come into close relation with these fossae. The posterior or *olecranon fossa* is deep, and receives the summit of the olecranon when the forearm is in full extension.

The *ossification* of the distal extremity of the humerus begins in the second or third year, when a center for the capitulum and outer half of the trochlea appears (Fig. 796). About the fifth year there develops a center for the medial epicondyle. At this time the medial and distal parts of the diaphysis grow downward and separate the medial epicondyle from the remainder of the epiphysis. The center for the remainder of the trochlea appears about the seventh year, and coalesces with the other two centers to form the true lower epiphysis of the humerus, which unites with the shaft about the twelfth year. The medial epicondyle has a separate epiphysis which appears in the fifth year, but remains separate from the other centers; it joins the shaft in the eighteenth or nineteenth year. Separation at the epiphysial line does not involve the medial epicondyle, which, even as late as the twentieth to twenty-fifth year, may be separated alone and be carried distally by its attached musculature. A fracture involving the epiphysis of the medial epicondyle is extra-articular.

The growth at the inferior humeral epiphysial line is relatively less important than that at the superior or fertile epiphysis, which is responsible for four fifths of the growth of the arm. Resection of the elbow performed in early youth limits the possibility for growth of the humerus to the upper epiphysial line.

The PROXIMAL EXTREMITY OF THE ULNA is the heaviest part of that bone (Fig. 797). The projecting *olecranon* and *coronoid processes* forming it are hook-shaped, the concavity of the hook being the semilunar notch which revolves upon the trochlea of the humerus. The coronoid process presents a small concave

facet, or *radial notch* (lesser sigmoid cavity), which, with the annular (orbicular) ligament, helps to form the socket within which the head of the radius rotates in the movements of pronation and supination. At the anterior surface of the base of the coronoid process is the *tuberosity of the ulna* for the attachment of the brachialis (anticus) muscle.

The *development* of the olecranon and coronoid processes of the ulna takes place almost entirely from a primary ossification center in the shaft where growth continues during childhood (Fig. 796). A secondary nucleus for the proximal part of the olecranon, to which the triceps muscle attaches, appears about the tenth year, and unites with the shaft about the seventeenth year. Because the bony prominences which produce a strong bony joint in the adult are developed only partially in childhood, elbow dislocations at that time are common.

The upper surface of the HEAD OF THE RADIUS is concave and rests against the capitulum of the humerus (Figs. 797, 798). The circular periphery of the head is covered with a band of cartilage for movement in the radial notch of the ulna, but it is not attached to the annular (articular) or the capsular ligaments; it has no stabilizing tendinous or ligamentous attachments. Fracture of the head not only may derange and flatten this rotating wheel surface, causing pain in pronation, but also may cause a mechanical block to flexion or extension.

The *development* of the upper extremity of the radius takes place largely from a secondary center which appears between the fifth and sixth years and forms the disk-shaped proximal epiphysis. It is united to the shaft between the eighteenth and twentieth years. The proximal epiphysis and part of the neck of the metaphysis are intra-articular. The epiphysial line is almost transverse.

CARRYING ANGLE. The transverse axis of the lower articular extremity slants medially and downward, forming an acute angle with the intercondyloid axis, the direction of which is at a right angle to the shaft of the bone. This obliquity is responsible for the lateral deflection of the forearm and the obtuse carrying angle of the forearm in complete extension and supination (Fig. 799, *B*). The transverse axis of the olecranon forms an outside angle of less than 90 degrees with the shaft of the ulna, a factor which contributes to the lateral angulation of the forearm. Midpronation masks the carrying angle by allowing the radius to come into direct line with the humerus, and is the position of the forearm in which the hand is used most frequently. When the midsupinated forearm is flexed acutely, the correspond-

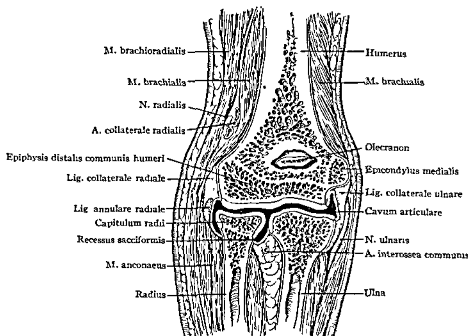


Fig. 797. FRONTAL SECTION OF THE BONES AND JOINTS OF THE ELBOW.

Large fat pad between the synovia and capsule, projecting into the olecranon fossa

Capsula articularis { pars fibrosa / pars synovialis

Olecranon

Trochlea

Capitulum humeri

Olecranon

Bursa subcutanea olecrani

Capitulum radii

Incisura semilunaris

Recessus sacciformis

M. anconaeus

Fig. 798. DEEP STRUCTURES OF THE POSTERIOR REGION OF THE RIGHT ELBOW.

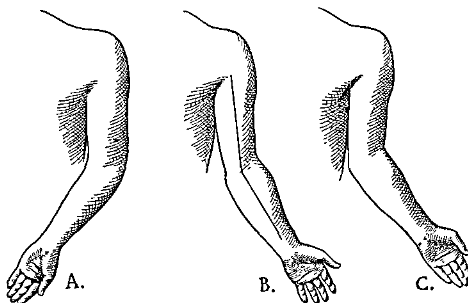


Fig. 799. VARIATIONS IN THE CARRYING ANGLE AT THE ELBOW.
A, Cubitus varus deformity; *B*, normal carrying angle; *C*, cubitus valgus deformity. (From Eisendrath, in Keen's Surgery.)

ing surfaces of the arm and forearm are applied accurately to one another.

When the supinated forearm is flexed fully with the arm at one side, the fingers lie over the medial half of the clavicle, and not over the apex of the shoulder. This does not imply medial rotation of the humerus, but illustrates that its anterior surface is directed medially as well as forward. To align the arm and forearm correctly after fracture about the elbow and to reproduce the carrying angle accurately, the fingers should lie in front of the inner half of the clavicle when the arm is flexed fully and supinated almost completely. An increase in the carrying angle is known as *cubitus valgus* (Fig. 799, C), and a decrease as *cubitus varus* (Fig. 799, *A*).

Ligaments and Synovia of the Elbow and Proximal Radio-ulnar Joints. The ligaments about the humerus and the bones of the forearm form a complete capsular investment for the elbow joint and the proximal radio-ulnar joint. The anterior and posterior parts of the *capsule* are relaxed into culs-de-sac in the respective positions of flexion and extension. In joint effusion the synovia bulges markedly into these pouches.

The *anterior* and *posterior ligaments* of the elbow are the anterior and posterior thickenings of the capsule. They are not strong, but are reinforced by the brachialis and triceps tendons. The *annular ligament* surrounds the head of the radius and is attached to the anterior and posterior margins of the radial notch of the ulna.

The *radial collateral* (*external lateral*) *ligament* extends fanwise from the lateral epicondyle into diverging bundles which pass over the head and neck of the radius (Fig. 797). The *ulnar collateral* (*internal lateral*) *ligament* extends fanwise from the medial epicondyle. Its fibers pass to the coronoid process and the margin of the semilunar notch.

The *synovia*, applied throughout to the deep surface of the capsule, pouches downward at the distal margin of the annular ligament for a varying distance around the neck of the radius. The pads of fat which fill the coronoid, radial and olecranon fossae are intracapsular but extrasynovial (Fig. 800). The fat pad occupying the radial fossa may become fibrocartilaginous, project into the joint, and cause locking and effusion.

Presence of fluid in the joint is manifest first in the paraolecranon groove on each side of the tendon of the triceps because of the weakness of the posterior part of the capsule in these areas. The deep fascia over the front of the elbow, reinforced by the lacertus fibrosus, is especially strong. If sinuses develop in connection with joint suppuration, they usually will be found on one or the other side of the

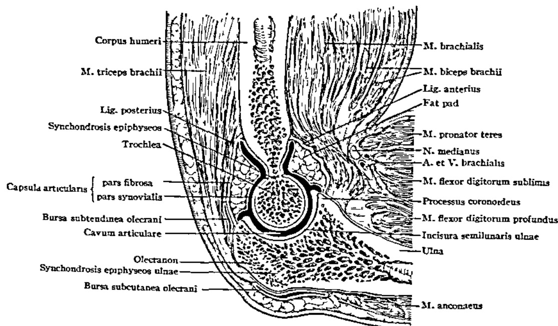


Fig. 800. SAGITTAL SECTION THROUGH THE ELBOW REGION.

triceps tendon. The joint may be *aspirated* from the lateral side by inserting a needle immediately proximal to the head of the radius.

BURSAE ABOUT THE ELBOW JOINT. The *radiohumeral bursa* lies over the radiohumeral joint between the extensor digitorum communis and the supinator brevis muscles. *Radio-ulnar bursitis* may occur from the irritation of repeated or violent extension of the wrist with the hand pronated—"tennis elbow."

The *interosseous bursa* is related laterally to the tendon of the biceps and medially to the ulna. It lies behind the supinator (brevis) muscle. The *bicipitoradial bursa* lies between the tuberosity of the radius and the insertion of the biceps muscle. Thus the biceps tendon runs between these two bursae, either or both of which may be irritated in engagements requiring violent movements at the elbow. When these bursae are diseased, they are painful upon contracture of the biceps muscle, especially if associated with supination of the forearm.

Surgical Considerations

EXAMINATION OF AN INJURED ELBOW. Often the diagnosis of lesions involving the elbow joint or the articular ends of the bones forming it is extremely difficult. In the light of the faulty functional results and unsightly deformities sometimes obtained, an injured elbow is a source of genuine perplexity and anxiety. A systematic examination should be made of the four bony prominences about the joint: the two epicondyles, the olecranon, and the head of the radius. Both active and passive motions of the joint should be tested. Unless the joint is examined soon after injury, the attendant difficulties are greatly increased by the swelling which rapidly supervenes and masks all landmarks. Without careful use of the roentgenogram many forms of fracture and dislocation are reduced improperly, so that, by the time the swelling has subsided, the resulting deformity may lead to ankylosis of the joint or a diminished range of movement.

SEPARATION OF THE DISTAL EPIPHYSIS OF THE HUMERUS. Separation of the distal epiphysis of the humerus is one of the commonest of the more severe elbow injuries occurring in childhood and adolescence (Fig. 801). After union of the epiphysis, supracondylar fracture may occur with a corresponding amount of trauma. Epiphysial separation often is accompanied by fracture across the distal part of the diaphysis. Separation of the epiphysis may occur before the sixteenth or seventeenth year, at which time the detached fragment usually includes the trochlea, capitulum and external epicondyle. The medial epicondyle, which develops from a separate center of ossification, is independent of the epiphysis proper and is extra-articular. Up to the age of five years the entire humeral cartilaginous extremity with its four developing centers may be torn from the shaft, and the lesion may simulate supracondylar fracture in deformity, swelling, discoloration, and mobility of the fragments. The epiphysis sometimes carries away a small part of the humeral diaphysis. Up to the age of sixteen or seventeen years epiphysial separation may be associated with posterior dislocation.

The displacement observed most commonly in epiphysial separation is that in which the epiphysis is carried backward with the forearm bones. The deformity then somewhat resembles posterior dislocation of both bones of the forearm. Because the periosteum is attached firmly to the epiphysial cartilage, it is carried with the epiphysis and is stripped up from the posterior part of the diaphysis for a varying distance. Unless the reduction is accurate, the stripped periosteum lays down new bone behind the humerus, which subsequently interferes with complete extension of the forearm. The difficulty in effecting reduction and in maintaining the parts in accurate apposition is great. To maintain reduction, the forearm is immobilized in full flexion.

Since the cartilaginous extremity is translucent to the x-ray, the condition is difficult to diagnose in children under three years of age, in whom the secondary centers of ossification are not yet developed.

FRACTURES INVOLVING THE DISTAL EXTREMITY OF THE HUMERUS. The distal extremity of the humerus is exposed to injury from falls on the outstretched hand because of the transmission of the force through the bones of the forearm. In children these injuries occur in great variety and number, and it is difficult in any case to ascertain the exact nature and direction of the fracturing force. It is not possible by examination and palpation alone to distinguish the exact nature of the fracture. The increased width of the humerus at this level, its flattened shape, its lessened strength resulting from the presence of the olecranon,

coronoid and radial fossae, and the superficial position of the epicondyles account for the frequency of fractures.

The *medial epicondyle*, because of its prominent position at the medial aspect of the elbow (Fig. 801), may be detached and subsequently displaced downward and forward by the flexor and pronator muscles of the forearm. The ulnar nerve, which is in close proximity to the bone, is often injured in this accident (Fig. 790).

A more extensive fracture of the *medial part of the distal extremity of the humerus* starts from the medial supracondylar ridge, and descends obliquely downward and outward through the olecranon and coronoid fossae and through the trochlea into the cavity of the elbow joint. The detached fragment, with the ulna, may rise above the normal level and produce inward deflection of the forearm. This deflection obliterates the carrying angle, carries the forearm into a cubitus varus position (Fig. 799, *A*), and interferes materially with the function of the limb. In the reduction of this fracture, care must be taken to avoid excessive mesial deflection of the forearm.

Fracture of the lateral epicondyle alone is rarely detected because of the small size and slight projection of the fragment (Fig. 801). A much more common lesion is a *fracture extending from the lateral epicondylar ridge into the elbow joint* through the capitulum or between the capitulum and trochlea. The lesion may be produced by a fall on the palm of the hand in which the force is transmitted through the head of the radius. The usual cause of this fracture is direct violence to the elbow, and a common complication is cubitus valgus (Fig. 799, *C*). This fracture of the lateral epicondyle, including a portion of the condyle and the capitellum, is usually rotated downward and lateralward about 90 degrees in each direction because of the pull on this fragment of the extensor tendons attached at this point. Because of this tendinous pull, manipulative reduction is seldom possible, and it is usually necessary to carry out an open reduction of this fragment and fixation by means of a single wire-nail, or occasionally catgut suture is sufficient to hold it in place. If reduction is not accomplished, the cubitus valgus which results leads in later life to ulnar nerve neuritis, which may require transposition anteriorly of the ulnar nerve or an osteotomy to correct the severe cubitus valgus.

The displacement in *transverse supracondylar fracture* is in the anteroposterior direction. The long fragment overrides the distal fragment, which, with the elbow, is carried backward by the pull of the triceps muscle. The deformity resembles that of posterior dislocation. Careful examination shows that the relation of the condyles to the olecranon is unchanged. This lesion has been described as an extension fracture, in contradistinction to the far less common flexion fracture caused by a blow on the back of the flexed elbow. In the latter the distal elbow fragment and the forearm are driven forward anterior to the proximal fragment. Supracondylar fractures frequently radiate downward through one of

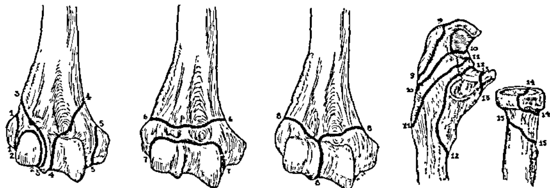


Fig. 801. LINES OF FRACTURE AND EPIPHYSIAL SEPARATION ABOUT THE DISTAL EXTREMITY OF THE HUMERUS, AND THE PROXIMAL EXTREMITIES OF THE RADIUS AND ULNA.

1–1, Fracture of external condyle; 2–2, fracture of capitulum; 3–3, fracture of external condyle; 4–4, fracture of internal condyle; 5–5, fracture of internal epicondyle; 6–6, supracondylar fracture; 7–7, epiphysial separation; 8–8–8, Y fracture; 9–9, fracture of olecranon (summit); 10–10, fracture of olecranon (middle); 11–11, fracture of olecranon (base); 12–12, coronoid fracture (base); 13–13, coronoid fracture (tip); 14–14, fracture of head of the radius; 15–15, fracture of neck of the radius.

the fossae into the joint, resulting in so-called T-*shaped* or Y-*shaped* (*transverse diacondylar*) *fractures* (Fig. 801, 8-8-8). The displacement is the same as that in transverse fracture. Callus usually encroaches on the anterior and posterior fossae and limits the range of motion in the joint.

Successful treatment of these fractures consists in accurate reposition of the fragments and in operative reduction for serious displacement. Acute flexion is maintained after the reduction of almost all these fractures, since in this position the lower end of the humerus is splinted by the tightening of the triceps tendon, the forearm muscles are relaxed, and *the elbow is in a position from which function* is regained most readily, as gravity and exercises subsequently bring back extension. If limitation of motion then occurs, whatever motion remains is of functional value. Although acute flexion is the surest way of holding the fragments in position, it is subject to serious risk, for, should there be hemorrhage and edema within the deep fascia, the flexion has so tightened the fascia and muscles that venous return may be cut off and a Volkmann contracture may occur (p. 855).

A Volkmann contracture is such a permanent and serious deformity that every safety measure possible must be taken to avoid its occurrence. Such measures include checking constantly the radial pulse as the elbow is brought into flexion; and after the radial pulse is obliterated, then to release the flexion 10 or 15 degrees. After the cast has been applied the radial pulse must be palpable and frequently checked. The onset of Volkmann's contracture is with severe pain about the elbow which should immediately be recognized as a warning symptom and immediately the cast split to reduce the flexion of the elbow and reduce the swelling. If there should be difficulty in obtaining a safe degree of flexion of the elbow or if the swelling has progressed too much before manipulation can be carried out, skeletal traction by means of a wire through the olecranon process of the ulna and supporting the elbow at 90 degrees makes a satisfactory way of supporting and reducing the difficult supracondylar fracture.

Deformities from unsatisfactory reduction of fractures of the distal end of the humerus are exceedingly common. Many of these fractures enter the joint and distort the articular surfaces. Because of the complexity of the *joint, there is* limitation of motion when only moderate displacement remains. Joint motion frequently is limited by adhesions within the muscles about the joint and by ossifying myositis.

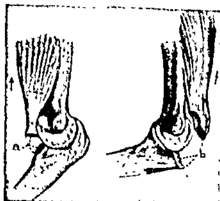


Fig. 802. FRACTURE ABOUT THE ELBOW FROM MUSCLE ACTION.

a, Contraction of the brachialis muscle has torn away the coronoid process of the ulna; *b*, contraction of the triceps has fractured the olecranon process. (From Babcock: Textbook of Surgery.)

FRACTURE OF THE OLECRANON PROCESS. The olecranon process, like the patella, surmounts the extensor surface of a joint and receives the pull of a powerful extensor muscle (Fig. 802). In many respects olecranon fracture resembles patellar fracture. The site of fracture of the olecranon varies; it may lie near the extremity of the process or cross it, so that the proximal fragment includes the proximal half of the semilunar notch, thereby involving the joint cavity. As a rule, the fracture is caused by the direct violence of a fall upon the point of the elbow. Muscle action probably plays an important role in producing the break, since the triceps muscle is likely to be in contraction at the time of the fall, thus throwing a great strain upon the bone. Muscle action alone may cause fracture. In this type of fracture the proximal fragment usually is a small piece of bone holding the triceps insertion.

In all fractures involving the olecranon the triceps muscle tends to draw the detached fragment upward (Fig. 802). This action is opposed by the lateral tendinous expansions investing the sides of the bone, by the ulnar collateral ligament, which often remains untorn, and by the ulnar periosteum, the anconeus muscle and the common ulnar periosteum. The degree of separation depends upon the extent to which these structures are torn. When wide separation occurs, difficulty *is experienced in keeping the fragments in*

apposition. It usually is necessary to expose the site of fracture, empty the joint of clots, and suture the fragments into position. After surgical reduction the arm need not be placed in full extension, as is required when the fragments are reduced by manipulation.

Fracture of the Neck of the Radius. The head of the radius is in the direct line of force applied through the hand and radius to the humerus. The radial head and neck also receive the brunt of rotary and torsion strains on the forearm. Fracture through the neck is fairly common. Displacement of the head may be forward, backward or lateralward; forward displacement is the most common. When the anterior ligament of the elbow joint and the annular (orbicular) ligament give way, the head moves forward anterior to the humerus and interferes seriously with the range of elbow movements. Flexion is limited at or near 90 degrees by the contact of the misplaced head with the forward surface of the inferior extremity of the humerus. Rotation is resisted strongly, pronation less so, and the hand is rendered useless for many purposes. Rotary movements can occur only at the shoulder.

The head of the radius lies as an unattached fragment in the elbow joint, produces an unusual fullness on the anterolateral aspect, and is subject to faulty union or nonunion. It should be removed, preferably through a dorsal incision between the extensor carpi-ulnaris and anconeus muscles. Removal of the head of the radius does not imply any disability or loss of function, provided the annular ligament is preserved or repaired. The head of the radius should not be removed in children because loss of the head will result in an increasing and serious cubitus valgus deformity during the growth at the elbow joint.

Subluxation of the Radius (Pulled Elbow). In young children sudden traction on, or torsion of, the hand or wrist may result in an anterior displacement of part of the head of the radius. The bone first is pulled downward through the annular ligament. The child cannot use the elbow, and carries the forearm in partial pronation, since supination is painful. Forcible supination screws the partially dislocated radial head back into position.

Dislocation at the Elbow Joint. In spite of its structural stability, exposure of the elbow to severe trauma causes dislocation to occur at the elbow joint with a frequency second only to that of the shoulder joint. The resistance offered by the bony elements of the joint sometimes is responsible for accompanying fractures. The bones of the forearm may be dislocated posteriorly, anteriorly, laterally or medially, and the dislocation in any direction may be partial or complete. The dislocated ulna carries the radius with it.

Posterior dislocation of both bones of the forearm is the most common dislocation at the elbow (Fig. 803). It results from a fall upon the outstretched hand with the forearm abducted and extended. As the line of force passes upward behind the transverse axis of the elbow joint, the forearm is hyperextended, and the anterior ligament and anterior part of the collateral ligaments are overstretched and give way. The articular surface of the humerus is pried from the semilunar notch and pushed forward over the coronoid process. The fibers of the brachialis muscle, which are attached to the coronoid process, are overstretched or torn. The dislocation is incomplete if the free edge of the coronoid process rests against the lower part of the trochlea, and complete if the coronoid process passes backward and upward and rests in the olecranon fossa.

In complete dislocation the head of the radius lies behind the lateral epicondyle, and the distal end of the humerus sinks into the cubital fossa. The arm and forearm are held in semiflexion and meet at an angle of about 120 degrees. The forearm appears shortened, the depth of the elbow is increased, and the olecranon projects posteriorly. The relations

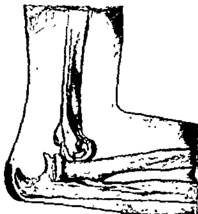


Fig. 803. Posterior dislocation of both bones of the forearm. The elbow is flexed to a right angle.

(From Scudder: *Treatment of Fractures.*)

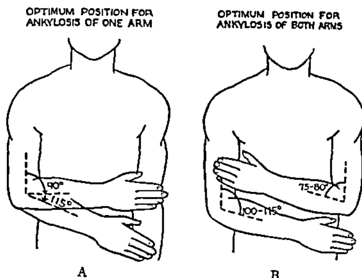


Fig. 804. OPTIMUM POSITION IN ANKYLOSIS OF THE ELBOW JOINT.
A, Position of choice when one elbow is ankylosed; *B*, position of choice when both elbows require fixation.

between the humeral epicondyles and the olecranon are altered. The olecranon lies above and behind its normal level, and its posterior projection is increased by attempts at flexion of the forearm. All movements, however slight, are painful.

Anterior dislocation of both bones of the forearm is the rarest of the elbow dislocations, and arises from trauma applied to the olecranon from behind when the elbow is flexed. In this position the olecranon lies anterior to the trochlea. If the acting force continues, the olecranon may be torn away from its ligamentous connections with the humerus and be driven forward, carrying the radius with it. The dislocation is incomplete if the summit of the olecranon comes to rest anterior to the trochlea, and complete if it comes to rest anterior to the distal end of the humeral shaft.

Lateral and medial dislocations occur from falls on the pronated, outstretched hand. The direction of dislocation depends upon whether the line of force is directed lateral or medial to the midpoint of the transverse axis of the elbow. Lateral dislocation usually is complete. In its least accentuated form of dislocation the head of the radius rests beneath the lateral epicondyle of the humerus, and the sharp free margin of the coronoid process lies in the groove between the trochlea and capitulum. In a more advanced stage of dislocation the radial head is lateral to the humerus, and the semilunar notch of the ulna lies beneath the capitulum and lateral epicondyle. In complete dislocation both forearm bones lie to the lateral side of the humerus. The forearm usually is rotated medially in such a way that the radius is directed forward and the ulna backward. Lateral dislocation occasionally is associated with posterior dislocation of the radius and ulna.

Medial dislocation is almost always incomplete. Its rare occurrence is explained by the downward projection of the medial lip of the trochlea. When the ulna clears this projection, the semilunar notch rests beneath the trochlea.

ANKYLOSIS OF THE ELBOW. If one elbow is to become ankylosed, it is best that it be fixed at an angle of 90 to 115 degrees, depending upon the patient's occupation (Fig. 804). If both elbows are fixed, the *right one* should be ankylosed at something greater than a right angle, and the left at something less than a right angle. The right hand then can be brought to the mouth. The left can be used for cutting food, and also can reach the trouser pocket. In all cases the forearm is put in a position midway between pronation and supination.

ARTHROPLASTY OF THE ELBOW. Arthroplasty of the elbow (formation of an artificial joint) is indicated for ankylosis in an unsuitable position, such as complete extension. If one elbow is ankylosed in flexion and the other in extension, an arthroplasty should be performed on the elbow in extension. If both elbows are ankylosed at a right angle or less, mobilization of one elbow is indicated.

The lateral incision (of Kocher) (Fig. 792) and the posterolateral approach afford sat-

isfactory access to the joint (Fig. 793). After the ulnar nerve has been dissected free a transverse incision is made through the soft parts and periosteum at the base of the olecranon. When the olecranon is sawed through, the whole joint may be broken open. The fasciae, capsule and ligaments are dissected from the bones, and the anteroposterior surface of the joint comes into view. If the joint is fused, the bony union is broken. After the articular ends have been brought out through the incision they are remodeled to articulate as smoothly as possible. Sufficient bone should be removed to allow free motion. An area of fascia lata is cut from the thigh, fashioned about the newly modeled humeral condyles, and sutured to the capsule. The detached portion of the olecranon process is then sutured to the ulna, and the wound is closed. Absorption of the tissue interposed between the bone ends results in the formation of a bursa-like structure which permits joint mobility.

Myositis ossificans, or the abnormal growth of bone in muscle, occurs near the brachialis and triceps insertions and is common after fracture or dislocation. The bone deposited interferes materially with flexion and extension.

VOLKMANN'S ISCHEMIC CONTRACTURE. This is a boardlike hardening of the forearm from fibrosis of the muscles, which are shortened and adherent to each other. Use of the fingers is lost, and there are sensory and motor changes. The contracture has been ascribed to compression of the arteries and anemic necrosis from immobilization in flexion or from applying splints and bandages too tightly. The condition actually is caused by edema and hemorrhage beneath the deep fascia which obstruct venous return and produce venous congestion. This blocks the drainage of the waste products of metabolism in the muscle and leads to an actual replacement of the muscle tissue by fibrous tissue.

COMPLICATIONS OF INJURIES ABOUT THE ELBOW. Watson-Jones* lists supracondylar fracture of the humerus first in the causes of palsy of the radial nerve, second as a cause of palsy of the median nerve, and fourth as a cause of palsy of the ulnar nerve. He also pointed out that most of the recorded instances of Volkmann's contracture were in the upper extremity and were due to involvement of the brachial artery at the level of a supracondylar fracture of the humerus.

According to Meyerding,** the mechanism of supracondylar fracture predisposes to neural and vascular injuries. The injuring force carries the condyles backward (Fig. 805), and this strips the periosteum away from the posterior surface of the proximal fragment, making a space which promptly fills with blood. Also, the lower end of the proximal fragment is carried forward and downward, piercing the anterior aspect of the periosteum and forcing its way against the soft tissues. The blood vessels and nerves thus become compressed by fragments of bone and by blood that infiltrates the antecubital fossa. The nerves may thus be contused, compressed, restricted by scar or lacerated. Similarly, the vessels may be compressed, contused, thrombosed, perforated or severed.

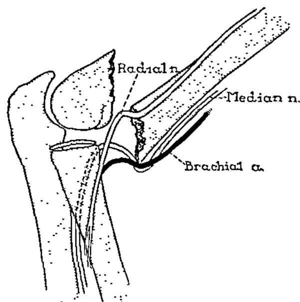


Fig. 805. THE MECHANISM OF INJURY OF THE BRACHIAL ARTERY AND THE MEDIAN AND RADIAL NERVES IN SUPRACONDYLAR FRACTURES OF THE HUMERUS.

The injuring force carries the condyles backward and strips the periosteum away from the posterior surface of the proximal fragment. This space promptly fills with blood. Also, the lower end of the proximal fragment is carried forward and downward, piercing the anterior aspect of the periosteum and forcing its way against the soft tissues. The blood vessels and nerves thus become compressed by fragments of bone and by blood that infiltrates the antecubital fossa. (From Lipscomb and Burleson: J. Bone & Joint Surg., 37-A, No. 3: 487–92, 1955.)

* Fractures and Joint Injuries. 4th ed. Baltimore, Williams & Wilkins Company, 1952, Vol. 1, pp. 111, 131, 136–8.

**J.A.M.A., 106: 1139–44, 1936.

In Lipscomb and Burleson's* series all the complications of note occurred in the *extension* type of supracondylar fracture. No vascular or neural injuries occurred in the *flexion* type, or in median and lateral condylar fracture in the fourteen-year or younger age group. When there was disturbance of circulation or motion, or sensation of the extremity distal to the injury, treatment of the fracture became secondary to the more important treatment of the extremity as a whole.

A summary of Lipscomb and Burleson's treatment of their cases of fresh supracondylar fracture can be stated briefly as follows: After a careful history of the injury and its treatment was obtained, the child was examined, and, if reduction was unsuccessful, immediate manipulation under general anesthesia was carried out. Usually, if the radial pulse was previously absent, it returned, and the forearm and hand lost its cyanotic appearance. If adequate circulation distal to the fracture was not present within twenty to thirty minutes after the manipulation and reduction, the brachial artery in the antecubital space was explored. Two patients had actual rupture of the brachial artery; two patients had thrombosis of the artery; in two patients the artery was stretched over proximal fragments of the humerus; the artery in one patient was found pinched in a longitudinal split in the proximal fragment of the humerus; in one patient a spicule of bone had impaled the artery. In six of those patients there was occlusive damage to the brachial artery and firm spasm unrelieved by any method. As noted by Leriche, these conditions result in prolonged spasm which is relieved by resection of the injured arterial segment. This procedure was carried out followed by 1 per cent procaine block of the stellate ganglion. With the excellent collateral circulation about the elbow, good circulation of the distal extremity was obtained. Early and adequate treatment of acute vascular injuries usually ensures a good prognosis, but delay may lead to serious and permanent disability.

Neurological injuries complicate from 12 to 15 per cent of supracondylar fractures. Of seventeen such instances in Lipscomb and Burleson's series, eleven involved the radial nerve, seven the median, and only two the ulnar nerve. Surgical exploration of these neural lesions was necessary in only four patients, and then only after three or four weeks of no improvement. At operation nerves were found not divided, but compressed by old hemorrhage, bound down by fibrous tissue or stretched over bone fragments.

* J. Bone & Joint Surg., 37-A, No. 3: 487–92, 1955.

CHAPTER 30

Forearm

Anterior and Posterior Regions of the Forearm

Definition and Boundaries. Topographically, the forearm extends from an imaginary horizontal line three fingerbreadths below the level of the elbow to the bend of the wrist. The forearm is considered in the supine position with the palm of the hand looking forward. The *anterior* or *volar region* contains all structures anterior to the plane of the radius and ulna, and includes the antero-internal (anteromedial) and antero-external (anterolateral) muscle groups arising from the medial and lateral epicondyles and the epicondylar ridges. The *posterior* or *dorsal region* contains the soft parts posterior to the shafts of the radius and ulna and their interosseous membrane. The extensor muscle group (Fig. 809), which composes the bulk of this region, is limited mesially by the posterior border of the ulna and laterally by the septum of the deep fascia of the forearm, which separates the extensors of the carpus from those of the hand.

Surface Anatomy. In full supination the forearm appears as a cone flattened anteroposteriorly. The increase in the transverse diameter near the elbow is caused by masses of muscle arising from the epicondyles of the humerus. The lessened bulk of the distal half of the forearm marks the transition of the fleshy portions of the muscles into their respective tendons. Distally, the shafts of the radius and ulna are superficial, and their contour is defined readily. The distal end of the radius, in passing from full supination to full pronation, carries with it the carpus and hand and revolves about the head of the ulna in such a way that the surfaces of the forearm become reversed.

The surfaces of the forearm present elevations separated by linear depressions which correspond to the subjacent muscles and the interstices and fascial septa between them. In children and in females, in whom the muscles are not prominent and in whom there is abundant subcutaneous fat, the forearm presents a uniform aspect with an almost cylindrical contour.

The anterior surface of the forearm is traversed by a shallow furrow which begins above at the level of the biceps tendon, and inclines slightly laterally as it descends to the medial side of the radial styloid. This groove marks the line of separation, between the antero-external group of muscles, composed of the brachioradialis and the radial extensors, and the antero-internal group of muscles, composed of the pronator (radii) teres and the flexor muscles. When flexion of the elbow is resisted, this groove is defined more clearly, and the brachioradialis muscle stands out prominently at the lateral aspect of the forearm. The groove marks the direction of the course of the radial artery. The vessel may be palpated readily in the lower part of the radial sulcus because of its superficial position and its proximity to the bone. The radial artery lies between the prominent tendons of the brachioradialis and flexor carpi radialis muscles.

Proximally, the individual flexor and pronator tendons cannot be distinguished easily under the deep fascia. Distally, their tendons are important surgical landmarks. By volar flexion of the hand against resistance, certain of the volar tendons at the wrist become unusually distinct. The tendon of the flexor carpi ulnaris lies nearest the medial border of the forearm, where it may be gripped between the fingers and thumb opposite the distal extremity of the ulna and be traced to its insertion into the pisiform bone. The ulnar vessels and nerves lie immediately to its lateral side. The tendon of the flexor carpi radialis lies just mesial to the

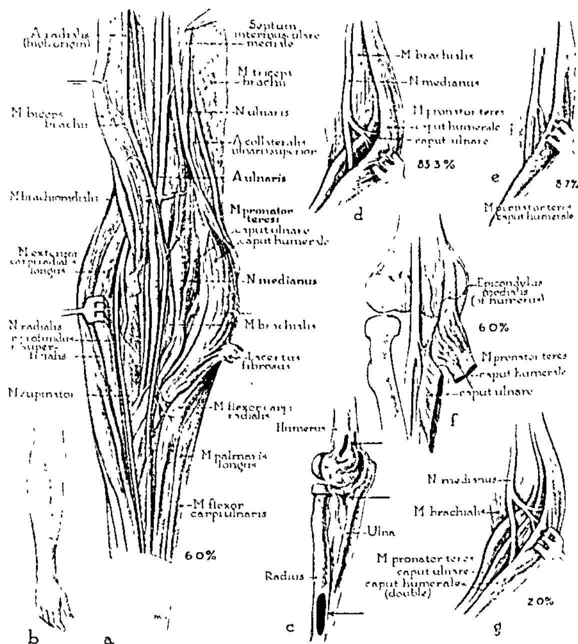


Fig. 806. VARIATIONS IN THE FORM AND ATTACHMENTS OF THE PRONATOR TERES MUSCLE AND IN ITS RELATION TO THE MEDIAN NERVE; PERCENTAGE OCCURRENCE OF TYPES IN 300 SPECIMENS.

b, The forearm in pronated position. *c*, The commonest areas of skeletal attachment of the pronator teres muscle: origin, from the medial epicondyle of the humerus and the corresponding aspect of the coronoid process of the ulna; insertion into ventral, lateral and dorsal aspects of the radius at the summit of the latter's chief curve. *a*, An infrequent type (6 per cent) in which the median nerve passes beneath the ulnar (deep) head of the pronator teres muscle. In this specimen there occurred a high (proximal) division of the brachial artery, to send the ulnar and radial divisions separately into the cubital fossa. Structures have been retracted in order to demonstrate the relationships of muscles, vessels and nerves in the latter region. *d*, The most frequent type (83.3 per cent), in which the nerve passes between the humeral (superficial) and ulnar (deep) heads of the pronator teres. *e*, One of the 3 infrequent types (8.7 per cent) in which the nerve, in the absence of an ulnar head of the pronator, passes to deep level in the antebrachium by coursing distalward under the humeral head. *f*, An even less common relationship between the pronator teres muscle and the median nerve (as in *a*), in which the nerve courses deep to the regular ulnar head. *g*, The least common arrangement (2 per cent), whereby, in the presence of an ulnar head, the median nerve passes between subdivisions of a split humeral portion of the pronator teres muscle. (From Jamieson and Anson: Quart. Bull., Northwestern Univ. M. School, 26: 34-5, 1952.)

navicular tubercle, and the radial vessels lie just lateral to it. The palmaris longus tendon stands out to the ulnar side of the flexor carpi radialis tendon and is the guide to the median nerve, which lies just beneath it or to its radial side (Fig. 808).

The posterior aspect of the forearm is narrower than the anterior aspect, but the contour is more rounded because of the longitudinal bulge representing the extensor and flexor musculature of the posterior region. The muscle mass of the flexor group is distinguished readily from the protrusion made by the brachioradialis and radial extensor muscles. The common boundary line of the two groups of muscles is the dorsal border of the ulna (Fig. 809), which is subcutaneous throughout its length and can be followed distinctly from the olecranon to the styloid process. The lateral boundary of the extensor group is less distinct, since it is formed by the lateral margin of the radius. In a muscular limb the lateral boundary is indicated by the linear sulcus, which lies along a line drawn from the lateral epicondyle to the dorsal radial tubercle and separates the radial extensor muscles from the extensor communis digitorum muscle. The abductor and the extensor muscles of the thumb cross the lateral surface of the radius obliquely below its center and form a soft, rounded projection (Fig. 811).

The tendons and much of the muscle mass

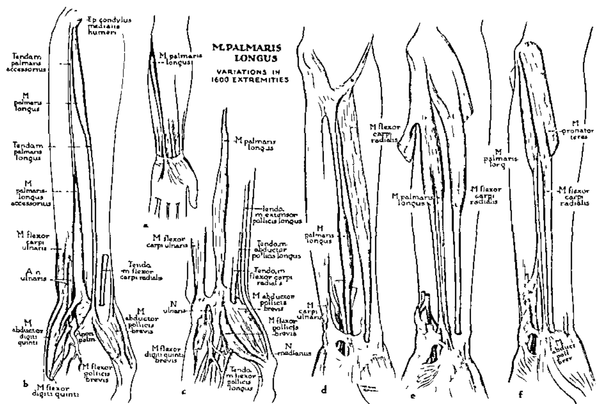


Fig. 807. PALMARIS LONGUS MUSCLE AND TENDONS. SELECTED VARIATIONS IN FORM AND ATTACHMENTS.

a, Regular form, course and attachments. *b*, Doubling of the muscle; the ulnar element possesses a distal muscular portion which receives a slip (at *) from the short flexor of the little finger. *c*, A single muscle, the position of the fleshy and the tendinous portions being the reverse of the normal arrangement. *d*, A specimen aberrant in respect to 2 features: a centrally placed muscular segment; a proximal slip (at *) derived from the lacertus fibrosus. *e*, A bifid palmaris longus (partial doubling of the fleshy segment, complete duplication of the tendon) *f*, A tendon separated in its distal third, the accessory (ulnar) slip becoming blended with the antebrachial fascia.

In 1600 extremities the palmaris longus muscle was absent in 205 cases (incidence, 12.9 per cent). The incidence of anomalies of all types, exclusive of agenesis, was 46 in 530 consecutive arms. Variations in position and form constitute one half of these (23 in 46). Accessory slips and substitute structures were encountered 15 times in the set of 46 anomalies, while duplication of the palmaris was encountered 4 times, aberrancies of attachment 3 times. (From Reimann, Daseler, Anson and Beaton: Anat. Rec., 89: 495–505, 1944.)

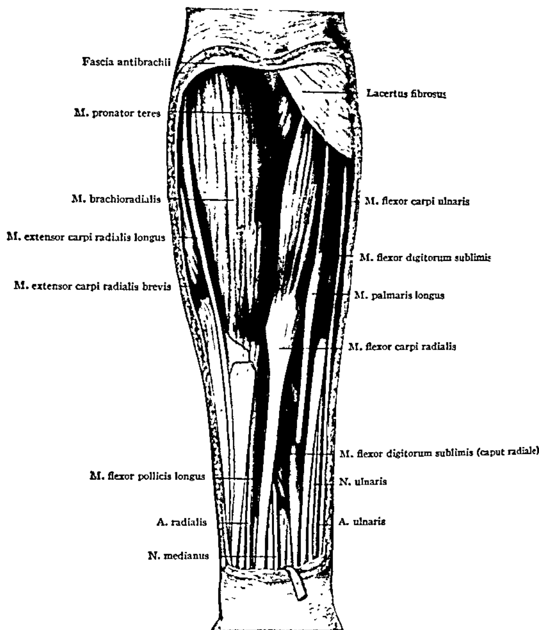


Fig. 808. SUPERFICIAL MUSCLES, VESSELS AND NERVES ON THE ANTERIOR REGION OF THE RIGHT FOREARM.

of the mesial or flexor muscle group pass forward around the ulna to the anterior or volar region of the forearm.

DEEP FASCIA OF THE FOREARM. The deep antebrachial fascia invests the forearm completely and is continuous with the deep fascia of the arm and hand. It is especially strong along the dorsal surface, and is attached to the olecranon process and the humeral epicondyles. It is strengthened around the elbow by expansions from the triceps brachii muscle. The deep fascia is reinforced anteriorly by the lacertus fibrosus (bicipital fascia), an expansion from the biceps tendon (Figs. 787, 788). At the wrist the deep fascia is continuous with the *transverse* and *dorsal carpal* (*annular*) *ligaments*. From its deep surface the fascia furnishes attachment to several muscles and sends *intermuscular septa* to the radius and ulna.

MUSCLES OF THE FOREARM. The forearm muscles are separated into three groups: antero-internal, antero-external, and posterior.

The ANTERO-INTERNAL OR FLEXOR-PRONATOR GROUP of muscles lies in a mesial, deep, fascial space, and includes the pronators and flexors arising from the medial epicondyle and the epicondylar ridge (Fig. 808). The more superficial of these, extending medially from the midline of the forearm, are the pronator teres, flexor carpi radialis, palmaris

longus, flexor digitorum sublimis and flexor carpi ulnaris muscles. With the exception of the flexor carpi ulnaris muscle, they are supplied just beyond the elbow joint by branches of the median nerve (C 6). The *pronator teres muscle* (N. median, C 6) has, in addition, a deep head of origin from the coronoid process of the ulna, to which the ulnar nerve may be related in any one of several ways (Fig. 806). The muscle is inserted into the middle of the lateral surface of the radius and is a powerful pronator as well as a flexor of the forearm. The *flexor carpi radialis muscle* is inserted into the bases of the second and third metacarpals and causes flexion and radial deviation of the hand at the wrist. If it acts in conjunction with the radial extensors, it effects radial deviation only. The *palmaris longus muscle* (N. median, C 6) terminates in a long, slender tendon which passes anterior to the transverse carpal (anterior annular) ligament to an insertion into the palmar fascia. Not infrequently the long palmar is absent; variations in form and attachments often occur (Fig. 807). The *flexor digitorum sublimis muscle* (N. median, C 7, 8; T 1) lies deep to the preceding tendons. Its individual tendons arise in the distal third of the forearm and pass behind the transverse (anterior annular) carpal ligament. It acts primarily as a flexor of the proximal interphalangeal joints, and secondarily as a flexor of the meta-

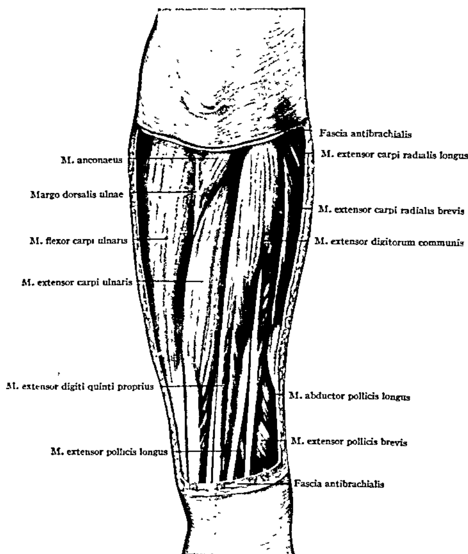


Fig. 809. SUPERFICIAL MUSCULATURE IN THE POSTERIOR REGION OF THE RIGHT FOREARM AFTER REMOVAL OF THE ANTEBRACHIAL FASCIA.

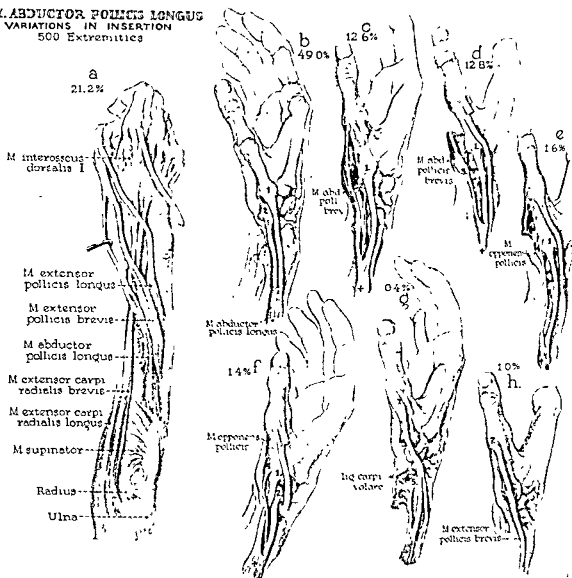


Fig. 810. TYPES OF INSERTION OF THE ABDUCTOR POLLICIS LONGUS.

a, Showing the full extent of the muscle, shown by removal of the extensor digitorum communis, extensor digiti quinti proprius, extensor carpi ulnaris and anconaeus. In this specimen insertion is limited to the first metacarpal bone. This regularly described type of attachment occurred in only 106 specimens, or approximately 21.2 per cent, of 500 extremities. *b* to *h*, Variations in the insertion of the tendon of the abductor pollicis longus muscle. The percentage occurrence of each type of insertion is recorded with the illustration of the sample specimens. In all, 7 structures (numbered) receive the insertion of the tendon. *b*, Insertion into both the first metacarpal bone (at 1) and the greater multangular (2). *c*, Insertion into the first metacarpal (1) and, additionally, the abductor pollicis brevis (3) and the greater multangular (2). *d*, Insertion into the metacarpal (1) and the abductor pollicis brevis (3). *e*, Insertion into the metatarsal (1) and the opponens pollicis (4). *f*, Insertion into the first metacarpal bone (1), greater multangular (2) and the opponens pollicis (4). *g*, Insertion into the styloid process of the radius (5), the volar carpal ligament (6) and the proximal phalanx of the thumb (7). *h*, Insertion through an accessory slip from the extensor pollicis brevis (1) in the absence of a muscular part of the abductor itself, the extensor passing to the regular attachment (7). (From Coleman, McAfee and Anson: Quart. Bull., Northwestern Univ. M. School, 27: 117–22, 1953.)

carpophalangeal, wrist and elbow joints. The *flexor carpi ulnaris muscle* (N. ulnar, C 8; T 1) descends along the ulnar border of the forearm to a principal insertion on the pisiform bone. If the flexor carpi ulnaris acts with the flexor group, it aids in flexing the wrist and elbow joint; if it acts with the extensor carpi ulnaris, it produces ulnar deviation of the hand.

The deep set of antero-internal muscles includes the flexor digitorum profundus, flexor pollicis longus and pronator quadratus. These muscles are supplied by the volar interosseous branch of the median nerve (C 7, 8; T 1), except for that part of the flexor digitorum profundus (N. ulnar, C 8; T 1) controlling the ring and small fingers. The *flexor digitorum*

profundus muscle arises from the volar and median surfaces of the ulna and from the interosseous membrane, and terminates in tendons which pass beneath the transverse carpal ligament, along with the tendons of the flexor digitorum sublimis muscle, to enter the digital sheaths of the four fingers. These tendons are inserted into the bases of the terminal phalanges; their primary action is to flex the terminal phalanges and, continuing this action, to flex the remaining phalanges and, finally, the hand. The *flexor pollicis longus muscle* (N. median, C 8; T 1) arises mainly from the volar surface of the radius and the interosseous membrane. Its tendon passes along the volar surface of the thumb to an insertion at the base of its terminal phalanx. The *pronator quadratus muscle* (N. median, C 8; T 1) is flat and quadrangular; it extends across the lower portions of the radius and ulna in the distal fourth of the forearm (Fig. 812).

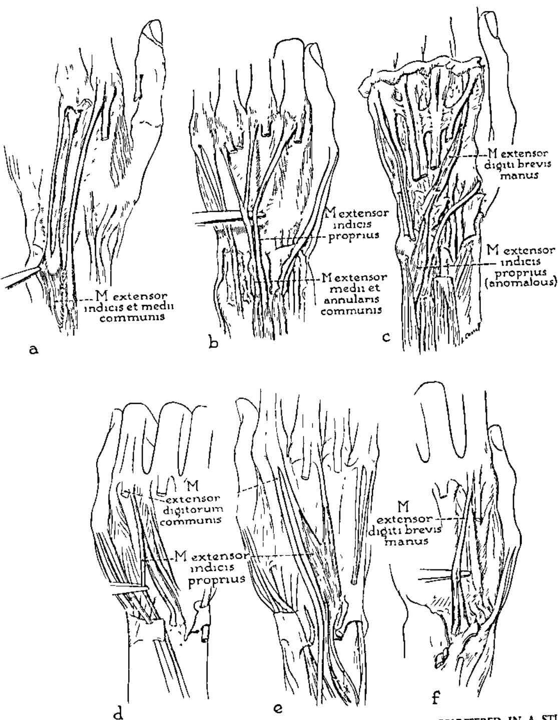
The ANTERO-EXTERNAL OR RADIAL GROUP of muscles springs from the lateral humeral epicondyle, and includes the brachioradialis (supinator longus) and the extensor carpi radialis longus and brevis muscles (Fig. 808). Under these muscles the upper part of the radial shaft is invested by the *supinator muscle.*

The *brachioradialis* (*supinator longus*) *muscle* (N. radial, C 5, 6) arises between the triceps and brachialis muscles from the lateral margin of the humerus, the lateral intermuscular septum, and the lateral epicondyle. It is attached by a long, thin tendon to the styloid process of the radius and flexes and somewhat supinates the forearm. The *extensor carpi radialis longus* and *brevis muscles* have a common origin from the lateral epicondyle and lateral intermuscular septum. Their tendons are inserted into the bases of the second and third metacarpals and extend the hand. The long extensor muscle is supplied by the deep division of the radial nerve (C 6, 7); the short extensor muscle by the dorsal interosseus branch of the radial nerve (C 6, 7). The *supinator* (*brevis*) *muscle* (deep branch of the radial nerve, C 6, 7, 8) is concealed almost wholly by the foregoing superficial muscles. It arises mainly from the lateral epicondyle of the humerus and the supinator crest and fossa of the ulna, and its diverging fibers are inserted into the posterior, lateral and anterior surfaces of the radius.

The POSTERIOR OR DORSAL GROUP of muscles is arranged in a superficial and a deep layer (Fig. 809). The superficial members of the group include the extensor digitorum communis, extensor digiti quinti proprius and extensor carpi ulnaris. The anconeus muscle (p. 845) belongs in the proximal part of this region. With the exception of a small branch of the radial nerve to the anconeus muscle, the deep ramus of the radial (posterior interosseus) nerve (C 6, 7, 8) supplies all the muscles in the posterior group. The *extensor digitorum communis muscle* arises mainly from the lateral epicondyle of the humerus and the deep fascia of the dorsal part of the forearm. Its four tendons are inserted into the bases of the middle and terminal phalanges of the four fingers. The *extensor digiti quinti proprius muscle* arises in common with the preceding muscle and accompanies its tendon to the little finger. The *extensor carpi ulnaris muscle* arises with the adjacent superficial extensors from the lateral epicondyle and the dorsal antebrachial fascia. Its tendon is inserted into the base of the fifth metacarpal (Fig. 861).

The deep group of extensors springs from the dorsal surfaces of the radius and ulna and is supplied by the deep branch of the radial nerve (C 6, 7, 8). The group includes the abductor pollicis longus, extensor pollicis brevis, extensor pollicis longus and extensor indicis proprius muscles. The *abductor pollicis longus* (extensor ossis metacarpi pollicis) muscle is described simply as inserting into the base of the metacarpal of the thumb. Actually, more complex forms of attachment occur with greater frequency (Fig. 810). The *extensor pollicis longus* and *brevis muscles* are inserted into the bases of the second and first phalanges, respectively. The *extensor indicis proprius muscle* is inserted with the tendon of the common extensor, which passes to the index finger (Fig. 861). Chronically neglected in standard accounts of dorsal antebrachial anatomy are the small accessory muscles and supernumerary tendons which pass from the deep layer into the metacarpal bones, most frequently to the radial side (Fig. 811).

ARTERIES OF THE FOREARM AND THEIR LIGATION. The ULNAR ARTERY is the larger of the two terminal trunks of the brachial artery (Fig. 812). From its origin (p. 840) at the neck of the radius it descends through the anterior surface of the forearm and crosses the transverse carpal ligament on the radial side of the pisiform bone. In the *lower two thirds* of the



811. EXTENSOR MUSCULATURE OF THE HAND. SELECTED VARIATIONS ENCOUNTERED IN A STUDY OF 263 SPECIMENS OF UPPER EXTREMITY.

An example of extensor of the index and middle fingers in which a lateral tendon inserted into the digit as would a ...cal extensor indicis proprius, while the other 2 tendons passed to the middle finger. *b*, A case in which a normal extensor ...cis proprius, arising in common with a distally placed portion, sent tendons to the index, middle and ring fingers. *c*, An ...nple of an extensor indicis brevis manus (that is, a short muscle arising in the hand), which was associated with an anoma... extensor indicis proprius. *d* and *e*, Bifid varieties of the same muscle. *f*, A short manual muscle to the index finger, com...ble to one portion of the typical extensor digitorum brevis on the dorsum of the foot (From Cauldwell, Anson and ...ight: Quart. Bull., Northwestern Univ. M. School, 17: 267-79, 1943.)

forearm the course of the artery is straight, and is indicated by a line drawn from the front of the medial epicondyle to the radial surface of the pisiform bone with the forearm in full supination. The artery lies upon the flexor digitorum profundus muscle between the flexor carpi ulnaris muscle mesially and the flexor digitorum sublimis muscle laterally. It gradually becomes superficial toward the wrist. In the *upper third* of the forearm the vessel is placed deeply between the superficial and deep layers of the antero-internal musculature. This part of its course is indicated by a slightly curved line beginning *2.5 cm. below the bend of the elbow at the* center of the limb, and extending mesially to meet the vertical course at the junction of the upper and middle thirds of the forearm.

The *volar* and *dorsal ulnar recurrent branches* are given off near the origin of the ulnar artery. The *common interosseous artery* arises farther distally (Fig. 812).

Ligation of the ulnar artery is usually performed near the wrist or at the junction of the upper and middle thirds of the forearm, where its curved and vertical portions meet. With the arm fully supine, the artery may be ligated in the upper forearm through an incision beginning a palmbreadth below the medial epicondyle. After exposure of the deep fascia the wound margins are retracted and the *white line nearest the ulnar border of the limb* is located. This line indicates the interspace between the flexor carpi ulnaris and flexor digitorum sublimis muscles, between and

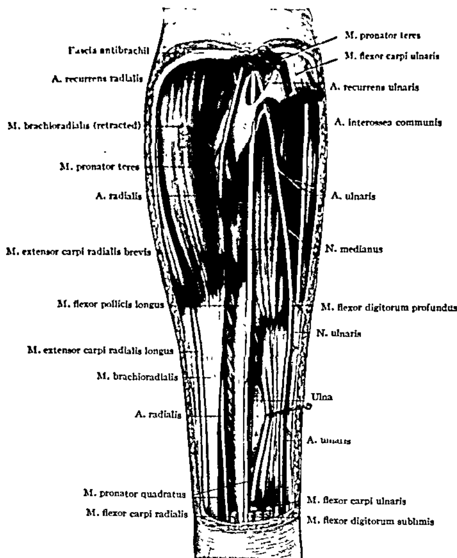


Fig. 812. DEEP MUSCLES, VESSELS AND NERVES OF THE ANTERIOR REGION OF THE RIGHT FOREARM.

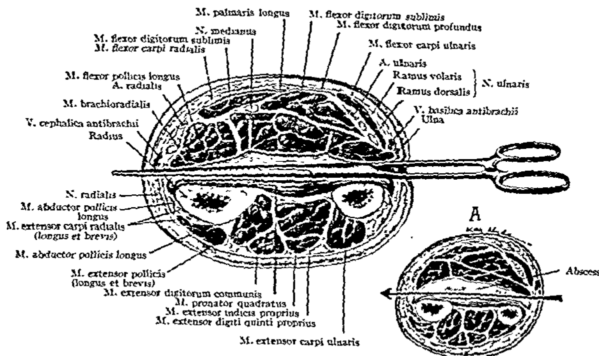


Fig. 813. CROSS SECTION THROUGH THE LEFT FOREARM 7 CM. PROXIMAL TO THE RADIAL STYLOID PROCESS

A, The path for incision of an abscess in the anterior region of the lower forearm, extending from infection in the carpal synovia.

A hemostat in inserted transversely in juxtaposition to the radius and ulna through the anterior interosseous space. Incision can be made here without injuring important vessels and nerves, and the abscess can be evacuated. Note the amount of tissue between the radial artery and the hemostat. (After Kanavel).

beneath which the artery lies. The ulnar nerve is more medially placed (Fig. 812).

In ligation of the artery at the wrist, incision is made through the deep fascia 2.5 cm. proximal to the flexion fold, in the interval between the flexor carpi ulnaris and the flexor digitorum sublimis muscles. Near the wrist the ulnar artery lies in the same relation to the ulnar nerve as it does in the upper forearm (Fig. 828).

The RADIAL ARTERY runs a fairly straight course through the forearm (Fig. 812). As it descends it inclines laterally gradually and, after reaching a point mesial to the radial styloid, enters its carpal course (p. 879) by passing beneath the extensor tendons of the thumb. Its course is indicated by a line drawn from the termination of the brachial artery (p. 828) to the navicular tubercle. In its *upper two-thirds* it lies under cover of the brachioradialis muscle and crosses the supinator muscle. The superficial (sensory) branch of the radial nerve approaches it on the lateral side. In the lower half of the forearm it lies between the brachioradialis and flexor carpi radialis muscles. Save where it is overlapped by the fleshy fibers of the brachioradialis muscle, the artery occupies a superficial position. The *distal third* of the artery is subcutaneous and lies on the radius and on the flexor pollicis longus muscle (Fig. 828).

The radial artery gives off two large branches in the forearm, the *radial recurrent artery* near its origin, and the *superficial volar artery* in the distal part of the forearm. The *superficial volar artery* runs through the short muscles of the thumb to meet the ulnar artery and complete the superficial palmar arch (Fig. 849).

Because the artery is superficial, *ligation of the radial artery* is performed readily at any part of its course in the forearm. In ligation in the upper third of the forearm the artery is found deep to the interval between the brachioradialis and pronator teres muscles.

For ligation of the artery at the wrist an incision is made over the artery midway between the outer border of the radius and the tendon of the flexor carpi radialis. The vessel lies upon the pronator quadratus muscle.

NERVES OF THE FOREARM. The nerves of the forearm are the median, the ulnar, and the superficial and deep branches of the radial (Figs. 788, 790, 812).

The MEDIAN NERVE enters the forearm be-

tween the superficial and deep heads of the pronator teres muscle (p. 858) and is separated from the ulnar artery by the deep head of that muscle (Fig. 812). It runs an approximately median course along the axis of the forearm. In the forearm it lies between the superficial and deep flexors of the fingers, and is attached firmly to the deep surface of the flexor digitorum sublimis.

The median nerve supplies all the superficial group of antero-internal muscles of the forearm, save the flexor carpi ulnaris, which is supplied by the ulnar nerve. By its *volar interosseous branch* it supplies all the deep group of antero-internal muscles except that part of the flexor digitorum profundus which controls the small and ring fingers; it is supplied by the ulnar nerve.

The ULNAR NERVE enters the forearm between the two heads of the flexor carpi ulnaris. It descends almost vertically upon the flexor digitorum profundus muscle and is overlapped by the flexor carpi ulnaris muscle (Fig. 812). Its *course* is indicated by a line drawn from the medial epicondyle to the lateral margin of the pisiform bone. In the upper part of the forearm the nerve is almost subcutaneous and can be rolled against the ulna. It is exposed by a vertical incision through the deep fascia over the medial paraolecranon groove, where it lies in contact with the mesial side of the elbow joint. *In violent flexion of the elbow the deep* fascia over the nerve sometimes is torn, allowing the nerve to slip forward around the medial epicondyle. This nerve dislocation may require operative replacement (p. 840). In the forearm it supplies the flexor carpi ulnaris muscle and the medial part of the flexor digitorum profundus muscle.

The SUPERFICIAL (SENSORY) BRANCH OF THE RADIAL NERVE descends beneath the brachioradialis muscle from an origin anterior to the

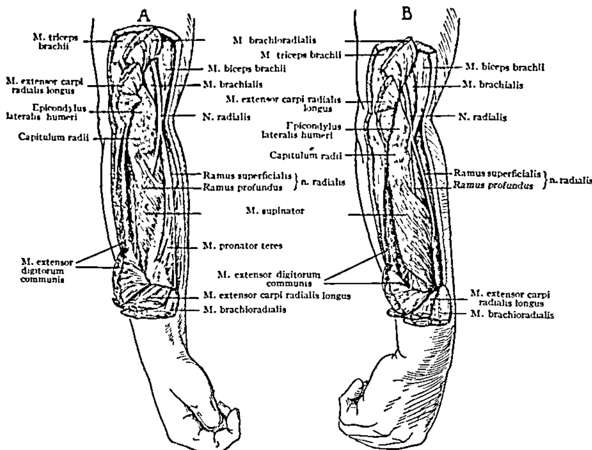


Fig. 814. RELATIONS BETWEEN THE DEEP BRANCH OF THE RADIAL NERVE AND THE RADIOHUMERAL JOINT AND PROXIMAL PART OF THE SHAFT OF THE RADIUS.

A, The forearm in full supination; *B*, the forearm pronated. With the forearm in pronation the radial nerve is not so likely to be injured in operations upon the proximal third of the radius.

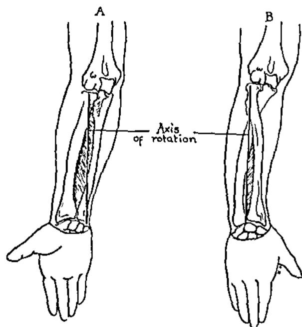


Fig. 815. RADIUS AND ULNA AND INTEROSSEOUS MEMBRANE IN THE POSITIONS OF SUPINATION AND PRONATION.

A, Supination; *B*, pronation.

lateral epicondyle. It approaches the radial artery and lies close to its lateral wall in the middle third of the forearm. About a palmbreadth from the radial styloid the nerve leaves the artery, pierces the deep fascia, and runs to the dorsum of the wrist and hand (Fig. 860).

The DEEP (DORSAL INTEROSSEOUS) BRANCH OF THE RADIAL NERVE reaches the back of the forearm by winding around the neck of the radius through the substance of the supinator muscle (Fig. 814). On reaching the lateral side of the shaft of the radius the nerve occupies the interspace between the superficial and deep muscles of the back of the forearm, and innervates them.

SHAFTS OF THE RADIUS AND ULNA. The radius and ulna differ in certain important features. The *ulna* is stronger and more massive in its proximal extremity. It is connected securely with the humerus, stabilizes the elbow joint, and is essential to flexion and extension. The shaft gradually tapers downward to its distal extremity, which plays only a minor role in the wrist joint.

The *radius*, in contrast, is weakest at its proximal extremity, where its articulation with the humerus is one chiefly of contact, and its presence is not essential to elbow movement. The shaft becomes stronger and wider toward its distal extremity, where it forms almost the entire forearm articulation at the wrist. At the middle of the forearm the radius and ulna are about equally strong, and their dimensions correspond closely.

With the forearm in supination the radius and ulna enclose the elliptical interosseous space, which is bridged by the *interosseous membrane* (Fig. 815). With increasing pronation the interosseous space gradually becomes narrower, and the interosseous ligament is relaxed until the two bones come into contact. In the thumb-up, semiprone position the interosseous space is widened. This position favors muscle relaxation, coaptation of fragments in fracture of one or both of the bones of the forearm, and the restoration of pronation and supination after immobilization for fracture. The range of pronation is increased considerably by internal rotation of the humerus at the shoulder joint. Partial or complete loss of pronation and supination is a common result of fractures and dislocations involving the bones of the forearm and the wrist and elbow joint, and is a serious disability.

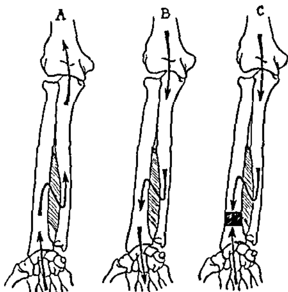


Fig. 816. ROLE OF THE INTEROSSEOUS MEMBRANE IN THE PATHOGENESIS OF FRACTURE OF THE RADIUS.

A, Shows how the force of a blow is transmitted to the arm through the radius, the interosseous membrane, and through the shaft of the ulna; *B*, Shows how force, acting through the arm, is transmitted to the hand. The force follows the ulna, the interosseous membrane, and then the radius. C, Shows the forces from below and above acting simultaneously, such as occurs in a fall upon the hand. The two forces meet in the shaded area in the distal extremity of the radius. (After Testut and Jacob.)

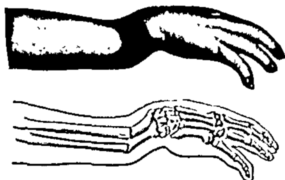


Fig. 817. FRACTURE OF BOTH FOREARM BONES NEAR THE WRIST.

Note that the deformity is a considerable distance proximal to the wrist joint. (Helferich.)

Surgical Considerations

COMBINED FRACTURE OF THE SHAFTS OF THE RADIUS AND ULNA. Fracture of both bones of the forearm, usually in the middle or lower third, occurs from direct or indirect violence (Fig. 817). Falls upon the hand are the usual cause. Only a small part of the shock is transmitted directly to the ulna; the greater part is transmitted to the distal extremity of the radius and up the shaft of the humerus. The radius transmits only a small amount of the shock to the ulna by the interosseous membrane, the fibers of which are directed downward and mesially. The fracture lines usually are transverse, but may have varying degrees of obliquity.

Displacement from overlapping of the fragments occurs when the fracture lines are oblique, and lateral displacement is likely to occur when fractures are transverse. There may be an angular displacement of both bones forward, backward or to either side, or the fragments may be approximated. Greenstick, incomplete or subperiosteal fractures of both bones are common, especially in children. In incomplete fracture in children the bones undergo a variable amount of bending, which produces an angular deformity of the forearm. The deformity should be overcome by straightening the limb forcibly while it is in the supine position. The forearm is grasped with both hands, and pressure is exerted by the thumbs against the projecting angulation. Lateral pressure should be avoided, since it tends to drive the forearm bones together and to lessen the interosseous space. While rotation is being effected, digital pressure is exerted in the interosseous area to separate the bones as widely as possible.

Certain tendencies to displacement should be borne in mind: the two bones are approximated by the action of the pronating muscles; the pull of the extensor and flexor muscles of the wrist, which arise from the humerus, tends to cause overriding of the fragments and shortening of the forearm and, even with accurate reposition of the fragments, to cause bowing at the point of fracture. Fractures in the distal part of the shaft usually are attended by overriding, the proximal fragments, as a rule, being anterior. The fragments of a fracture in the distal part of the shaft tend *to be drawn together by the pronator quadratus* muscle.

FRACTURE OF THE SHAFT OF THE ULNA. Fracture of the shaft of the ulna alone usually *is transverse and is caused by direct violence,* such as is sustained in warding off a blow directed at the head (Fig. 818). The direction of the force producing the fracture *determines the displacement,* which *usually is not* great. The fracture may occur from indirect violence from a fall upon the ulnar border of the hand; in this case it usually occurs in the distal third of the shaft, where the tendons replace the attached muscle masses (Fig. 819). The fracture often is compound, because the dorsal margin of the bone is subcutaneous throughout its extent. Marked displacement of the fragments is not common, because of the splinting action of the intact shaft of the radius, but there is a tendency to a narrowing of the interosseous space, either from the displacement from the blow or from the pull of the pronator quadratus muscle upon the lower fragment.



Fig. 818. FRACTURE THROUGH THE UPPER THIRD OF THE SHAFT OF THE ULNA, COMPLICATED BY ANTERIOR DISLOCATION OF THE HEAD OF THE RADIUS.

The proximal fragment is flexed by the brachialis muscle. The distal fragment is drawn toward the radius by the pronator quadratus muscle. (From Babcock: Textbook of Surgery.)

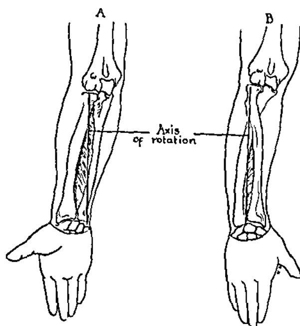


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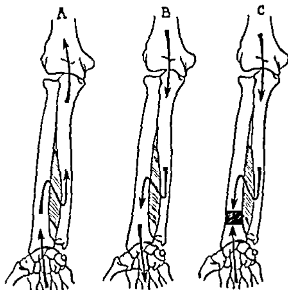


Fig. 816. ROLE OF THE INTEROSSEOUS MEMBRANE IN THE PATHOGENESIS OF FRACTURE OF THE RADIUS.

A, Shows how the force of a blow is transmitted to the arm through the radius, the interosseous membrane, and through the shaft of the ulna; *B*, Shows how force, acting through the arm, is transmitted to the hand. The force follows the ulna, the interosseous membrane, and then the radius. *C*, Shows the forces from below and above acting simultaneously, such as occurs in a fall upon the hand. The two forces meet in the shaded area in the distal extremity of the radius. (After Testut and Jacob.)

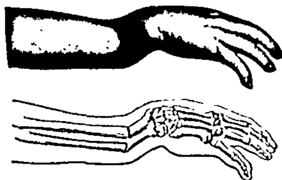


Fig. 817. FRACTURE OF BOTH FOREARM BONES NEAR THE WRIST.

Note that the deformity is a considerable distance proximal to the wrist joint. (Helferich.)

Surgical Considerations

COMBINED FRACTURE OF THE SHAFTS OF THE RADIUS AND ULNA. Fracture of both bones of the forearm, usually in the middle or lower third, occurs from direct or indirect violence (Fig. 817). Falls upon the hand are the usual cause. *Only a small part of the shock is transmitted directly to the ulna*; the greater part is transmitted to the distal extremity of the radius and up the shaft of the humerus. The radius transmits *only a small amount of the shock* to the ulna by the interosseous membrane, the fibers of which are directed downward and mesially. The fracture lines usually are transverse, but may have varying degrees of obliquity.

Displacement from overlapping of the fragments occurs when the fracture lines are oblique, and lateral displacement is likely to occur when fractures are transverse. There may be an angular displacement of both bones forward, backward or to either side, or the fragments may be approximated. Greenstick, incomplete or subperiosteal fractures of both bones are common, especially in children. In incomplete fracture in children the bones undergo a variable amount of bending, which *produces an angular deformity of the forearm.* The deformity should be overcome by straightening the limb forcibly while it is in the supine position. The forearm is grasped with both hands, and pressure is exerted by the thumbs against the projecting angulation. Lateral pressure should be avoided, since it tends to drive the forearm bones together and to lessen the interosseous space. While rotation is being effected, digital pressure is exerted in the interosseous area to separate the bones as widely as possible.

Certain tendencies to displacement should be borne in mind: the two bones are approximated by the action of the pronating muscles; the pull of the extensor and flexor muscles of the wrist, which arise from the humerus, tends to cause overriding of the fragments and shortening of the forearm and, even with accurate reposition of the fragments, to cause bowing at the point of fracture. Fractures in the distal part of the shaft usually are attended by overriding, the proximal fragments, as a rule, being anterior. The fragments of a fracture in the distal part of the shaft tend *to be drawn together by the pronator quadratus* muscle.

FRACTURE OF THE SHAFT OF THE ULNA. Fracture of the shaft of the ulna alone usually *is transverse and is caused by direct violence*, such as is sustained in warding off a blow directed at the head (Fig. 818). The direction of the force producing the fracture *determines the displacement, which usually is not* great. The fracture may occur from indirect violence from a fall upon the ulnar border of the hand; in this case it usually occurs in the distal third of the shaft, where the tendons replace the attached muscle masses (Fig. 819). The fracture often is compound, because the dorsal margin of the bone is subcutaneous throughout its extent. Marked displacement of the fragments is not common, because of the splinting action of the intact shaft of the radius, but there is a tendency to a narrowing of the interosseous space, either from the displacement from the blow or from the pull of the pronator quadratus muscle upon the lower fragment.



Fig. 818. FRACTURE THROUGH THE UPPER THIRD OF THE SHAFT OF THE ULNA, COMPLICATED BY ANTERIOR DISLOCATION OF THE HEAD OF THE RADIUS.

The proximal fragment is flexed by the brachialis muscle. The distal fragment is drawn toward the radius by the pronator quadratus muscle. (*From Babcock: Textbook of Surgery.*)

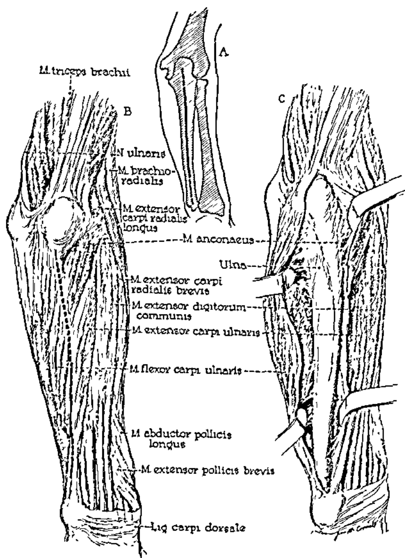


Fig. 822. POSTERIOR APPROACH TO THE SHAFT OF THE ULNA.

The posterior surface of the ulna is practically subcutaneous. Any segment of the shaft can be exposed by the appropriate longitudinal skin and subcutaneous incision, followed by subperiosteal reflection of the muscles.

pronation (Fig. 821). The supinating action of the biceps and supinator muscles is counteracted by the pronator teres muscle, which acts at a greater mechanical advantage. The distal fragment is pronated and drawn toward the ulna by the pronator quadratus muscle. The proximal fragment in this fracture is sufficiently long to be controlled so as to prevent rotary displacement. For reduction the forearm is placed in the thumb-up midprone position, that is, with the palm of the hand facing the chest. This attitude ensures correct apposition of the fragments and is the most comfortable position.

Surgical Approaches to the Bones of the Forearm. The *ulna* may be exposed readily throughout its extent, without injury to any important structure, by incision along its posterior margin, which lies between the extensor and flexor carpi ulnaris muscles (Fig. 822).

A *posterior approach to the distal two thirds of the radius* gives wholly satisfactory exposure for any surgical procedure (Fig. 823).

Boyd's exposure of the *upper third of the ulna and proximal third of the radius* (Fig. 824) provides an excellent view of these structures while at the same time affording ample protection of the radial nerve. The approach is also serviceable for correction of fracture of the upper end of the ulna and dislocation or fracture of the head of the radius. Boyd also used

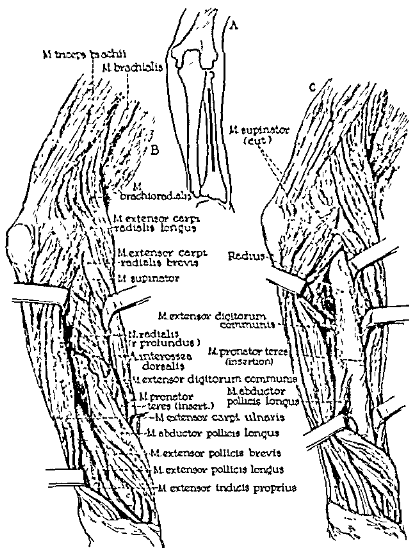


Fig. 823. POSTERIOR APPROACH TO THE SHAFT OF THE RADIUS.

A, Posterior incision of appropriate length over the shaft of the radius. *B*, The deep fascia is divided to expose the lateral edge of the extensor digitorum communis muscle, which is retracted medially. In the upper part of the wound this exposes the supinator muscle, which is pierced by the radial nerve. The dorsal interosseous artery also comes into view. As shown by the dotted line, the supinator is divided anteriorly to protect the radial nerve and is carefully retracted posteriorly. *C*, In the lower half of the radius the abductor and short extensor to the thumb are retracted ulnarward and the bone exposed subperiosteally. The insertion of the pronator teres should be identified and spared unless the procedure requires its removal.

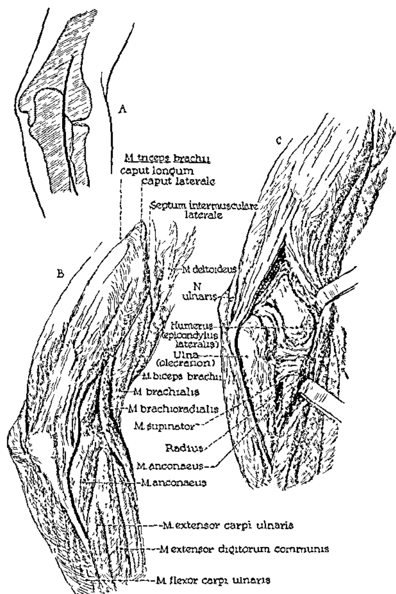


Fig. 824. APPROACH TO THE UPPER THIRD OF THE ULNA AND PROXIMAL FOURTH OF THE RADIUS (BOYD).

A, The skin incision begins just lateral to the triceps tendon an inch above the elbow joint, and extends downward over the lateral tip of the olecranon and along the subcutaneous edge of the ulna to the junction of its middle and upper thirds. *B*, The deep fascia is incised between the medial edge of the triceps tendon and ulna on one side and the anconeus on the other. *C*, The anconeus and the supinator are reflected subperiosteally from the ulna and retracted laterally. This exposes the posterolateral capsule of the elbow joint and permits development of the radius with little danger of injury to the deep branch of the radial nerve, which lies in the substance of the supinator. The approach may be used for exposure of the radius alone, but is particularly valuable for Monteggia fractures.

Note that in contradistinction to *B*, in *C* the triceps has been split, thus affording adequate exposure for complete exploration of the elbow joint. If the procedure calls for access to the proximal end of the radius on the lateral joint compartment, the incision as in *B* along the lateral border of the triceps is entirely adequate.

the approach for a fracture of both bones of the forearm at the junction of the upper and middle thirds.

A posterior approach to the lower end of the radius (Fig. 825) is an excellent incision for the treatment of malunited fractures of the distal end of the radius, excision of the radial styloid, and for biopsy and excision of bone tumors.

AMPUTATION THROUGH THE FOREARM. It is advisable, in all cases of amputation, to save as much of the forearm as possible to facilitate the subsequent wearing of an artificial limb. Supination and pronation should be preserved whenever possible. If the bone is divided below the level of the insertion of the pronator teres muscle, rotary movement is possible.

Amputation at the junction of the middle with the lower third gives the best stump from a prosthetic and surgical standpoint. The circulation in the skin at this level is good, the skin is tough, the subcutaneous layer is thick, and there is much muscle substance. Pronation and supination are preserved if the bone ends and the interosseous tissues and periosteum are dealt with to prevent excessive callus formation.

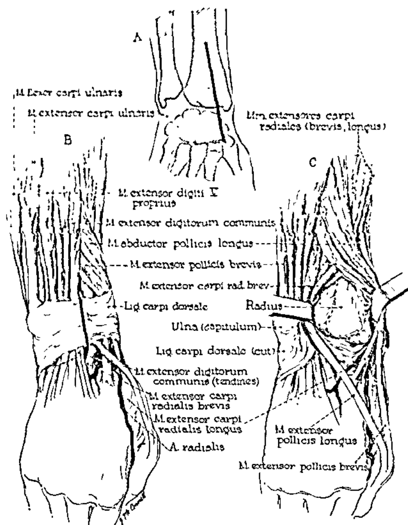


Fig. 825. APPROACH TO THE LOWER END OF THE RADIUS.

A, The 3-inch skin incision extends from the styloid process upward and slightly medially. *B*, The dorsal carpal ligament is incised just lateral to the extensor digitorum communis tendons. *C*, The lower posterior end of the radius is then exposed by medial retraction of the extensor digitorum communis muscle and the tendon of the extensor pollicis longus, and lateral retraction of the abductor pollicis longus and extensor pollicis brevis muscles and the tendon of the extensor carpi radialis.

CHAPTER 31

Wrist

The wrist is the mobile, flexible link between the forearm and hand. It may be said to include the soft parts and bones and joints over an area embracing not only the carpus, but also the bony extremities of the radius and ulna and the bases of the metacarpals articulating with it. It includes the radiocarpal, midcarpal and carpometacarpal joints. In the wrist the forearm tendons and their synovial sheaths proceed to their insertions in the carpus. They are maintained in close contact with the wrist bones by specialized thickenings of the deep fascia, an arrangement ensuring strength and graceful contour, and permitting the remarkable freedom of movement essential to the marvelously intricate functions of the hand.

Soft Parts of the Wrist

Surface Anatomy. The relative positions of the important *tendons*, *vessels* and *nerves* on the flexor surface of the wrist are important because of the frequency of lacerating wounds at this level. By flexing the wrist forcibly, or against resistance, the tendons stand out prominently. Starting where the radial pulse is felt and palpating mesially, the important tendons can be identified. The first tendon encountered is that of the flexor carpi radialis (Fig. 812) as it passes to its insertion on the bases of the second and third metacarpal bones. The tendon of the palmaris longus, which lies in the midline of the wrist and inserts into the palmar fascia, is felt mesial to it. Next in succession are the tendons of the flexor digitorum sublimis. The median nerve lies between the palmaris longus and flexor carpi radialis tendons. The flexor carpi ulnaris tendon occupies the ulnar side and terminates on the pisiform bone. The ulnar nerve and vessels lie between this tendon and those of the flexor digitorum sublimis, and occupy a superficial position. The flexor digitorum profundus and flexor pollicis longus lie on a deeper plane and are concealed on superficial inspection. Abscesses which originate in the digital (p. 915) and palmar (p. 903) synovia point between these structures; they may be propagated to the carpal synovia about the flexor tendons at the wrist.

A number of *bony prominences* of the anterior wrist are important landmarks (Fig. 826). Laterally, the expanded distal extremity of the radius is palpable. Its lateral border projects distally into a strong styloid process, at the base of which is a prominent ridge for the attachment of the brachioradialis tendon. The radial styloid process is more prominent, descends lower, and lies on a more anterior plane than the ulnar styloid process. The ulnar styloid is felt most readily at the mediodorsal side of the wrist with the forearm in lax pronation. It marks the radiocarpal joint level fairly accurately. A line joining both styloid processes crosses the wrist obliquely and is considerably below the highest point of the curve described by the joint line. The head of the ulna sometimes stands out in strong relief, rendering the otherwise graceful contour of the wrist somewhat unsightly. When there is lateral bowing of the lower end of the radius, deflecting the hand toward the radial side, the head of the ulna forms a prominence on the dorsal surface of the wrist (Madelung's deformity). The hand is carried ventrally on the articular surface of the radius.

The tubercle of the navicular (scaphoid) bone may be palpated at the radial side of the distal skin crease, and the pisiform bone occupies a corresponding position on the ulnar side. The latter bone is identified readily by allowing the hand to hang in the flexed position to relax the pull of the flexor carpi ulnaris muscle. The hook of the hamate (unciform)

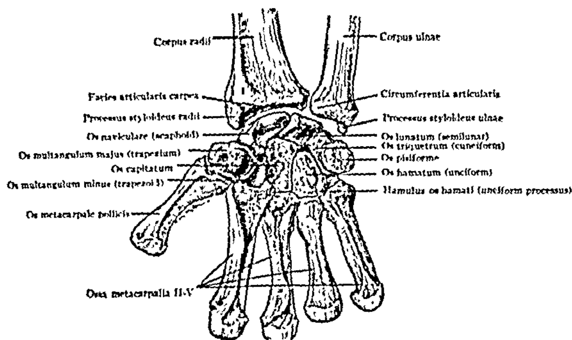


Fig. 826. ANTERIOR VIEW OF THE DISTAL EXTREMITIES OF THE RIGHT RADIUS AND ULNA AND THE CARPUS AND METACARPUS.

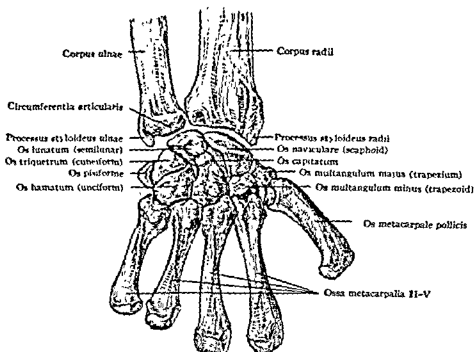


Fig. 827. POSTERIOR VIEW OF THE DISTAL EXTREMITIES OF THE RIGHT RADIUS AND ULNA AND THE CARPUS AND METACARPUS.

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proximally beyond the transverse carpal ligament and distally into the palm and fingers (palmar and digital synovia) (Figs. 849 to 853). The median nerve is superficial at the wrist and is injured by minor lacerations. It enters the carpal canal lateral to the flexor digitorum sublimis muscle.

Dorsal Carpal (Posterior Annular) Ligament. The dorsal carpal (posterior annular) ligament is a thick derivative of the deep fascia of the forearm which crosses the back of the wrist obliquely upward and medially (Fig. 861). It occupies a more proximal level than the transverse carpal ligaments. Laterally, it is attached to the lateral margin of the lower extremity of the radius and its styloid process, and mesially to the styloid process of the ulna and the ulnar border of the carpus. Septal processes or partitions pass from the deep aspect of the dorsal carpal ligament to ridges on the subjacent radius and ulna, forming separate osteofascial tunnels for the extensor tendons and their synovial sheaths. As these tendons pass beneath this ligament, they cross the thin posterior ligament of the radiocarpal joint (p. 882). In places this underlying ligament is so thin that, when the extensor tendons are deflected from their grooves, small protrusions of the radiocarpal synovia are brought into evidence as the hand is flexed and extended. An abscess on the dorsum of the wrist may penetrate the ligament and involve the radiocarpal and carpal joints.

Vessels and Nerves. The *radial artery* at the wrist lies superficially under the deep fascia of the forearm on the flexor pollicis longus and pronator quadratus muscles and the lower expanded extremity of the radius (Fig. 828). It enters the wrist in a groove between the brachioradialis tendon laterally and the flexor carpi radialis tendon mesially. At the level of the radial styloid it gives off a superficial volar branch which passes distally over the ball of the thumb and the transverse carpal ligament to aid in the formation of the superficial palmar arch (Fig. 849). Distal to the radial styloid process, the main trunk of the artery winds over the radial collateral (external lateral) ligament under cover of the abductor pollicis longus and extensor pollicis brevis muscles, and reaches the triangular depression (anatomical snuffbox) at the lateral and dorsal aspects of the wrist (Fig. 861). After reaching the proximal extremity of the first interosseous space the artery passes between the two heads of the first interosseous muscle to reach the palm, where it takes part in the formation of the deep palmar arch (p. 898).

The ulnar artery enters the region at the radial side of the pisiform bone, where it is held on the transverse carpal ligament by a fascial expansion (Fig. 828). The pisiform bone is a guide to ligation of the artery at this point. The artery divides into a superficial and a deep branch. The superficial branch continues the course of the parent artery and helps to form the superficial palmar arch. The deep branch passes through the transverse carpal ligament to contribute to the deep palmar arch.

About a handbreadth proximal to the radial styloid, the *superficial* or *sensory branch of the radial nerve* leaves the path of the radial artery to gain access to the dorsum of the wrist by passing under cover of the brachioradialis muscle. It is a purely sensory nerve and terminates on the back of the hand (Figs. 846, 860). Injuries to the nerve produce characteristic findings (p. 918).

The *median nerve* is superficial in the wrist and is exposed in minor lacerations. It enters the region between the tendons of the palmaris longus and flexor carpi radialis muscles, and lies to the radial side of the tendons of the flexor digitorum sublimis muscle, which it accompanies into and through the carpal canal under the transverse carpal ligament (Figs. 808, 828).

The *ulnar nerve* enters the wrist in company with and mesial to the ulnar artery and its satellite veins (Fig. 828). With these vessels, it is contained within a thin fascial investment bound down to the transverse carpal ligament on the radial side of the pisiform bone.

Bones and Joints

The wrist includes the distal extremities of the radius and ulna, the two rows of carpal bones, and the bases of the metacarpals (Figs. 826, 827, 829, 830). These bones are arranged into a series of joints: the radiocarpal, midcarpal and carpometacarpal, which act as an extremely flexible unit to enable the hand to perform its specialized functions.

On their volar surfaces (Fig. 826) the bones and joints are arranged in a spreading groove, narrow proximally and widening out into the palm. The carpal groove is converted into an

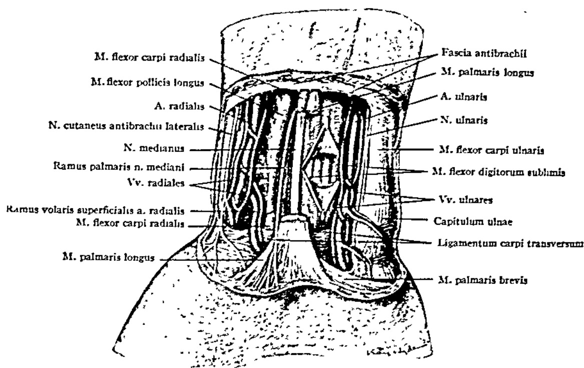


Fig. 828. DEEPER STRUCTURES OF THE ANTERIOR REGION OF THE WRIST.

bone lies a little distal to the pisiform on a line with the ulnar margin of the metacarpal of the ring finger. The ridge on the multangulum majus (trapezium) lies immediately distal to the navicular tubercle.

On the dorsolateral aspect of the wrist a shallow triangular depression, the *anatomical snuffbox*, is visible when the thumb is extended. The tendons of the abductor pollicis longus and the extensor pollicis brevis muscles bound the fossa on the radial side of the wrist, and the tendon of the extensor pollicis longus forms the boundary on the ulnar side. The floor of the depression contains the apex of the styloid process of the radius, the navicular (scaphoid), multangulum majus (trapezium), and base of the metacarpal of the thumb. The floor is crossed by the radial artery coursing from the front of the wrist posteriorly to the proximal extremity of the first interosseous space. Direct pressure in the floor of the fossa elicits tenderness when there is a fractured navicular (p. 888).

TRANSVERSE CARPAL (ANTERIOR ANNULAR) LIGAMENT; CARPAL CANAL AND ITS CONTENTS. The *transverse carpal* (*anterior annular*) *ligament* is a specialized portion of the deep fascia of the forearm. It is a tough, fibrous, anterior band stretched across the arch formed by the carpal bones, making a canal or tunnel for the conveyance of the flexor tendons and the median nerve from the anterior compartment of the forearm into the central compartment of the palm. On the radial side the ligament is attached to the tubercle of the navicular (scaphoid) and the ridge on the multangulum majus (trapezium), which together form the radial eminence. It is attached on the ulnar side to the ulnar eminence, which consists of the pisiform and the hook of the hamate. The ligament is continuous along its proximal margin with the deep fascia of the forearm, and it merges distally into the palmar fascia.

The palmaris longus tendon expands anterior to the transverse carpal ligament and inserts into the central part of the palmar aponeurosis. The ulnar nerve and artery cross the ligament into the palm immediately to the radial side of the pisiform bone (Fig. 828). Laterally, the ligament is crossed by a superficial volar branch of the radial artery, which extends into the palm to help form the superficial palmar arch (Fig. 849).

The flexor tendons passing through the *carpal canal* under the transverse carpal ligament are provided with two synovial sheaths, one for the flexor pollicis longus muscle, and another for the closely grouped tendons of the flexor digitorum sublimis and profundus muscles. Their sheaths (carpal synovia) extend

The *elliptical distal articular surface* that receives the proximal row of carpal bones is concave from side to side and anteroposteriorly. On the ulnar side the concave surface is roughly quadrilateral for the play of the convex surface of the lunate (semilunar) bone. Toward the radial styloid the surface is triangular, with still greater concavity to accommodate the movements of the navicular (scaphoid) bone. The anterior and posterior margins of this surface project downward and deepen the articular surface, giving attachment to the corresponding ligaments of the wrist joint. The dorsal margin of the articular surface extends farther distally than the volar margin. As a consequence, the plane of the radial articular surface faces distally and slightly toward the volar aspect. This plane must be maintained in the reduction of fractures about the lower end of the radius.

The radial styloid process extends distally farther than does the ulnar styloid. The bistyloid line roughly parallels the radial articular surface. Therefore the radial articular surface faces distally and slightly toward the ulnar side (Fig. 831).

The *center of ossification* for the distal end of the radius appears about the third year and is developed fully by the fifteenth year. The *epiphysial line* is about 1 cm. proximal to the joint margin and is extra-articular. Bony union is complete between the twentieth and twenty-fifth years; this is the fertile radial epiphysis where bone growth is greatest and most prolonged. Radial osteomyelitis which begins in the metaphysis does not involve the radiocarpal joint, but may invade the distal radio-ulnar joint.

Distal Extremity of the Ulna and the Articular Disk. The *distal extremity of the ulna* is expanded only slightly from the neck into a small rounded head (Fig. 830). The distal surface of the head is flat for articulation with the articular disk (Fig. 831). The narrow circumference of the head, save where the ulnar styloid projects, is an articular arc applied to the radial notch, affording a wide range of rotation in the distal radio-ulnar joint. The base of the styloid process is roughened for the attachment of the apex of the *articular disk*. This attachment and that of the ulnar collateral ligament explain the frequent wrenching away of the ulnar styloid in wrist trauma. The distal articular surface of the disk participates in the more elaborate radiocarpal joint.

The *center of ossification* for the distal extremity of the ulna appears between the sixth and ninth years, and the epiphysis is fused with the shaft by the twentieth year. The *epiphysial line* lies at a higher level than that of the radius, but is intrasynovial with respect to the distal radio-ulnar joint.

Carpal Bones. Each of the carpal bones is composed of close-meshed cancellous bone

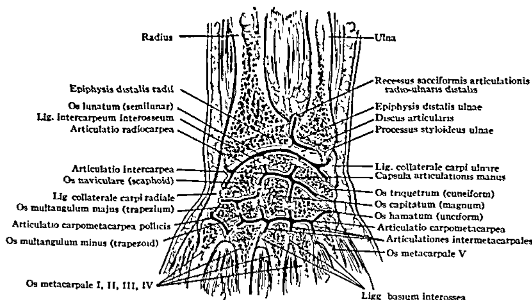


Fig. 831. FRONTAL SECTION THROUGH THE FOREARM AND HAND TO SHOW THE BONES, JOINTS AND LIGAMENTS.

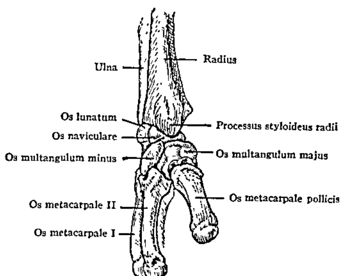


Fig. 829. LATERAL VIEW OF THE BONES OF THE LEFT WRIST, RESEMBLING THE APPEARANCE IN A ROENTGENOGRAM.

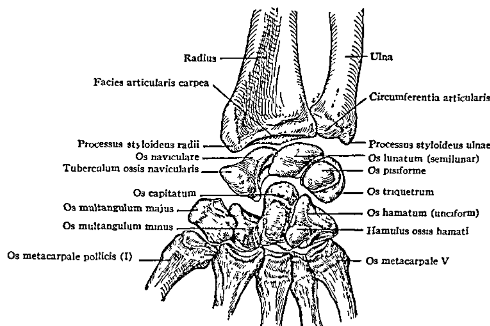


Fig. 830. ROWS OF CARPAL BONES AND THE BONES WITH WHICH THEY ARTICULATE.

osteofibrous canal by the transverse carpal ligament, which extends across the anterior surface of the carpus from the radial to the ulnar eminence.

DISTAL EXTREMITY OF THE RADIUS. The expanded distal extremity of the radius is large and well developed to support and control the hand in its variety of movements (Fig. 830). The spongy tissue is encased within a thin layer of compact bone. The pronator quadratus muscle is attached to its slightly flattened anterior surface, and over it the forearm structures pass into the carpal canal without obstruction. The *posterior surface* is ridged and grooved to accommodate and direct the extensor tendons to the dorsum of the hand. The styloid process is the distal prolongation of the *lateral surface*, and into its base the tendon of the brachioradialis is inserted. The *mesial surface* presents a concave articular facet for the reception of the articular surface of the head of the ulna, and a narrow ridge, to which the base of the triangular fibrocartilage, the articular disk, is attached. The disk is attached by its apex to the base of the styloid process of the ulna (Fig. 831).

is the stronger. They are reinforced by the flexor and extensor tendons. The radial collateral (external lateral) ligament extends from the radial styloid to the navicular bone and is crossed by the carpal portion of the radial artery. The ulnar collateral (internal lateral) ligament is attached above to the ulnar styloid and below to the triquetrum (cuneiform) and pisiform bones. The strength of the joint depends largely upon these collateral ligaments.

Aspiration of the joint may be performed immediately distal to the tip of the styloid process of the ulna between the flexor and extensor carpi ulnaris tendons.

CARPAL JOINTS. The junction of the two rows of carpal bones forms the *midcarpal joint*. This joint is surrounded by a complete capsule, strengthened by dorsal, volar and lateral ligaments, and is reinforced by fibers derived from the tendons. The midcarpal joint has an extensive synovial cavity which not only corresponds to the interval between the two rows of the carpus, but also extends upward and downward between the bones of each row. It frequently communicates with the synovia of the *carpometacarpal joints*. The carpometacarpal joint of the thumb and the joint between the triquetrum and pisiform bones maintain separate synovial cavities which do not communicate with the midcarpal synovial cavity.

Prolongations of joint synovia sometimes present on the dorsum of the wrist as synovial cysts or *ganglia* (Fig. 832). These circumscribed cystic swellings are of a firm, elastic consistency, hemispherical or spherical in outline. Sometimes they are cystic protrusions of the synovial sheaths of the extensor tendons at the wrist, but they may arise independently of the joint or tendon synovia as cystic degenerations of connective tissue. Their contents are gelatinous. Treatment consists in careful excision.

MOVEMENTS. The main movements at the wrist joint are executed through the transverse and anteroposterior axes. Forward (volar) flexion and backward (dorsal) flexion are effected through the transverse axis, and adduction (radial deviation) and abduction (ulnar deviation) through the anteroposterior axis. A combination of these movements and pronation and supination allows circumduction of the hand. Exaggeration of these movements causes rupture of the ligaments.

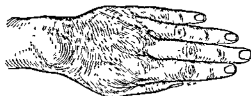


Fig. 832. GANGLION OF THE CARPUS.

The slight projection of the two styloid processes facilitates radial and ulnar deviation; whereas, in contrast, the projecting malleoli of the tibia and fibula almost prohibit lateral movements of inversion and eversion. Of the lateral movements at the wrist, ulnar deviation has the more extensive range. Radial deviation is checked by the ulnar collateral ligament and by contact of the greater multangular with the radial styloid process, which projects downward to a considerably lower level than the ulnar styloid. Dorsal and volar flexion, particularly volar flexion, are enhanced by the gliding movements between the proximal and distal rows of carpal bones at the midcarpal joint. Exaggerated movements in volar and dorsal flexion rupture the volar or dorsal carpal ligaments and may result in carpal dislocation with or without associated fracture of the navicular and dislocation of the lunate. The numerous intercarpal joints give elasticity to the hand and thereby increase its ability to withstand the effects of severe shocks, such as falling upon the outstretched palm. Any lateral displacement in the midcarpal joint is resisted strongly by the concavo-convex configuration of the joint.

Surgical Considerations

The close relations between the bones and joints of the wrist and the overlying ligaments, tendons, synovial sheaths, vessels and nerves explain the varying degrees of disabling and deforming arthritis, periarthritis and tenosynovitis which may occur after trauma.

COLLES' FRACTURE. The radius, through the rigidly bound carpus, bears the brunt of shocks transmitted through the hand. If the reinforcing ligaments and tendons resist this trauma, the usual occurrence is a transverse fracture of the lower extremity of the radius, Colles' fracture (Fig. 833). The *fracture line* usually is located within 3 cm. of the radiocarpal joint; when the fracture occurs proximal to this level, it partakes of the characteristics of fracture of the shaft (p. 871). The most fre-

within a shell of compact bone. Their joint surfaces are covered with cartilage, but the remaining surfaces are roughened for the attachment of their periosteocapsular covering. The dorsal surface of the carpal mosaic is slightly convex, but the palmar surface is markedly concave, with its margins elevated into radial and ulnar eminences for the attachment of the transverse carpal ligament and the formation of the carpal canal (p. 878).

The BONES OF THE PROXIMAL ROW in order from the radial to the ulnar side are the navicular (scaphoid), lunate (semilunar) and triquetrum (cuneiform). The pisiform lies on the volar surface of the triquetrum, with which it articulates (Figs. 826, 827).

The *navicular*, because of its curved shape and obliquely curved axis, is not adapted to withstand the indirect blow it receives in falls upon the palm with the hand in radial deviation. If the fall occurs with the hand in ulnar deviation, only the proximal part of the bone is exposed to trauma. The navicular is the most commonly fractured carpal bone. The *lunate*, the middle bone of the row, presents distally a moon-shaped articular surface which, with a part of the distal navicular articulation, lodges the head of the capitate bone (os magnum). It is the carpal bone most subject to dislocation. After traction on the hand it sometimes may be reduced manually. The *triquetrum* (cuneiform) presents part of its proximal surface for articulation with the articular disk and part for articulation with a specialized surface on the ulnar collateral ligament. This mechanism permits the triquetrum, with the *pisiform* on its volar aspect, to glide toward the ulna in ulnar flexion. The remainder of its proximal surface is nonarticular. The distal concavities of the triquetrum, navicular and lunate bones make a deep depression in which the capitate and hamate bones are lodged (Fig. 831).

The proximal row of bones presents an elongated, convex joint surface for articulation with the radius and with the articular disk. The pisiform bone *does not enter into the* radiocarpal joint. The distal articular surface of this unit is uneven. The navicular bone presents like a prow to articulate with the two multangular bones.

The BONES OF THE DISTAL ROW in order from the radial to the ulnar side are the multangulum majus (trapezius), multangulum minus (trapezoid), capitate (os magnum) and hamate (unciform). The *capitate* is the central, most prominent and strongest bone of this row (Figs. 826, 827). The force of a fall upon the hand is distributed to the radius through the head of the capitate, which articulates in the saddle formed by the navicular and lunate. The capitate articulates distally with the base of the third metacarpal.

Within the first year, *ossification centers* appear for the capitate and the hamate. In the third year a center appears for the triquetrum; in the fifth, for the lunate; in the sixth, for the greater multangular and the navicular; in the seventh, for the lesser multangular; and, about the tenth, for the pisiform. The rule that each carpal bone ossifies from one center has many exceptions. A bone may ossify from two or even three centers, a confusing condition in an x-ray study of carpal injuries. The navicular presents this variation most frequently.

BASES OF THE METACARPALS. The bases or carpal extremities of the metacarpal bones as a unit present a fairly even joint surface for the distal row of carpal bones. They are broad and cuboidal, and articulate with each other in the carpal mosaic type of compact arrangement.

DISTAL RADIO-ULNAR JOINT. A triangular fibrocartilage, the articular disk, excludes the ulna from the radiocarpal joint (Fig. 831). The disk is attached by its apex to the base of the styloid process of the ulna, and by its base to the ulnar margin of the distal end of the radius. The joint capsule, which fuses distally with the articular disk, is lax and weak and permits pronation and supination. In these motions the ulna is stationary and is the axis about which the radius rotates. The synovia bulges upward between the radius and ulna beyond the level of the distal epiphysial lines. Volar and dorsal radio-ulnar ligaments maintain a close-fitting but movable joint. If the disk is perforated, the synovia is continuous with that of the radiocarpal joint.

RADIOCARPAL JOINT OR WRIST JOINT PROPER. The lower extremity of the radius, in conjunction with the articular disk and the proximal row of carpal bones, forms the radiocarpal joint. Their articular surfaces are united by a capsule reinforced by *dorsal, volar and lateral* ligaments.

The volar and dorsal radiocarpal ligaments have little strength, but, of the two, the volar

There may be impaction of the distal fragment into the proximal fragment. The impaction may be such as to cause the whole circumference of the compact bone of the proximal fragment to penetrate the lower fragment, or the compact bone of the proximal fragment to overlap the corresponding layer of the distal fragment. The most common variety of impaction is that in which the distal fragment, with or without being displaced backward, hinges upon the proximal fragment so that there is impaction of the dorsal portions of both fragments. The carpal articular surface of the distal fragment then looks dorsally as well as distally.

Colles' fractures require immediate reduction under relaxing anesthesia to obtain perfect alignment. All three major deformities must be corrected: i.e., the length of the radius should be restored, the dorsal angulation of the articular surface of the radius should be returned to the normal position of volar angulation of 10 to 15 degrees, and the radial deviation should be corrected. In severely comminuted fractures, skeletal traction with a pin through metacarpal I or metacarpals II, III and IV may be needed to maintain correction. When reduction has been accomplished, the surface markings, even in the presence of swelling, can be palpated and seen. There must be a restoration of the normal relations between the styloid processes, a uniform dorsal plane along the forearm through the wrist to the hand, and a normal axial relation of the hand and wrist to the forearm. By correct reduction, deformities, stiff joints and limited movement with associated loss of power are avoided. The hand and wrist are immobilized in a position of volar flexion and ulnar deviation for two to six weeks, depending upon the stability of the fracture at the time of reduction and the degree of comminution, and the like. The original cast is best applied from the proximal flexion crease of the hand, holding the hand in palmar flexion-palmar deviation, the wrist in pronation, and the elbow at 90 degrees of flexion. This original cast should be above the elbow to prevent rotation of the forearm. The palmar portion of the hand should not extend below the proximal flexion crease, so that free function of the fingers while the wrist is supported in the cast can be carried out; and this free function and use of the fingers should be encouraged constantly. Stiffness of the metacarpal-phalangeal and interphalangeal joints occurs quickly when immobilized and may well lead to a much greater disability than would have resulted from the fracture alone. Volar flexion overcomes the backward tilt of the distal radial fragment. The hand soon can be brought into the functional position of slight dorsiflexion at the wrist and ulnar deviation. A strain to the shoulder joint with the possibility of subsequent stiffening should not be overlooked. In many older patients it is not discovered until removal of the forearm cast that the trauma to the shoulder and the enforced immobilization of the arm often have caused as much disability as that arising from the wrist injury.



Fig. 835. RADIAL DEVIATION OF THE HAND IN FRACTURE OF THE RADIUS.

It has been demonstrated (Abbott and Saunders) that median nerve injury in fracture of the radius sometimes results from pressure of the nerve between the sharp proximal margin of the transverse carpal ligament and the prominent anterior border of the lower end of the radius (Fig. 836). Nerve pressure is especially likely to occur when palmar hyperflexion is chosen as the position of fixation after fracture reduction.

REVERSED COLLES' FRACTURE (SMITH'S FRACTURE). The reversed Colles' fracture (Smith's fracture) usually is caused by a fall on the back of the hand with the wrist flexed (Fig. 837). The line of force passes through the anterior surface of the distal end of the radius, and the distal fragment is displaced forward and proximally.

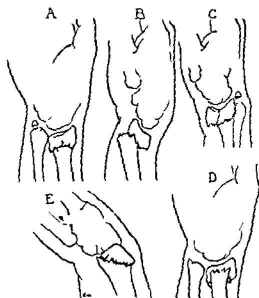


Fig. 833. VARIETY OF FRACTURES AT THE LOWER END OF THE RADIUS.

A, Transverse fracture of the radius with impaction, and fracture of the ulnar styloid process; *B*, severe grade of typical Colles' fracture with marked posterior displacement of the distal fragment and anterior tilting of the proximal fragment (silver-fork deformity); *C*, comminuted fracture of the radius into the joint and dorsal displacement of the head of the ulna; *D*, Colles' fracture of the radius with marked dorsal displacement of the distal fragment; shortening of the forearm is indicated by the bistyloid line transverse to the long axis of the forearm; *E*, fracture of the posterior margin of the articular surface of the radius (Barton's fracture).

quent cause of Colles' fracture is a fall upon the outstretched hand. It is probable that, when the impact is received upon the palm, the long axis of the forearm is inclined to the ground at an angle of less than 60 degrees. The line of force passes through the distal end of the radius instead of passing upward along the bone, as it would were the forearm at an angle of more than 60 degrees. A great strain is thrown upon the front of the wrist, which overstretches the anterior ligaments. The line of force drives the carpus against the radius, with the result that the lower extremity of the radius is broken. It is evident that the resisting power of the ligaments is greater than that of the lower end of the radius, where the expansion of bone is not accompanied by corresponding increase in strength.

The *usual displacement* in Colles' fracture is the backward or dorsal angulation of the distal articulating surface of the radius, the shortening by impaction and supination of the distal end of the radius and the radial angulation. The styloid process of the ulna is also commonly fractured.

There may be displacement of the distal fragment without impaction. In addition to dorsal displacement of the distal fragment and hand, there may be rotation about the transverse axis, so that the radial articular surface and styloid process look dorsally as well as distally (p. 880). In this rotation the distal fragment hinges upon the articular disk, the radial styloid rises to the same level or even higher than the styloid of the ulna, and the hand is thrown into radial deviation. If the traumatizing force is excessive and continues to act, the strain it throws upon the articular disk may bring about fracture of the ulnar styloid. If the disk, ulnar collateral ligament, and ligaments of the inferior radio-ulnar joint are torn, the lower extremity of the ulna may protrude through the skin.

In a typical fracture with the displacements just noted, the diagnosis can be made at a glance by the characteristic deformity of the wrist, which has been compared aptly to the outline of a silver fork (Fig. 834; in contrast, Fig. 835). Sometimes the degree of displacement is slight and there are no symptoms or objective findings at the wrist other than pain and swelling; the injury may easily be mistaken for a sprain.

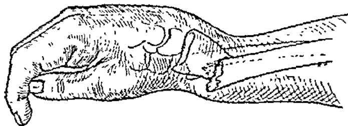


Fig. 834. SILVER-FORK DEFORMITY OF THE FOREARM AND HAND IN FRACTURE OF THE RADIUS.

The diagram illustrates the dorsal displacement of the distal fragment and the volar displacement of the proximal fragment.

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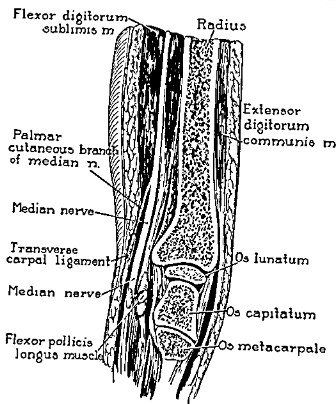


Fig. 836. SAGITTAL SECTION THROUGH THE RIGHT WRIST TO ILLUSTRATE THE VULNERABLE POSITION OF THE MEDIAN NERVE BETWEEN THE PROMINENT ANTERIOR MARGIN OF THE DISTAL EXTREMITY OF THE RADIUS AND THE TRANSVERSE CARPAL LIGAMENT.

(From Abbott and Saunders: Surg., Gynec. & Obst., 57: 507–16, 1933.)

After reduction of the deformity the alignment of the fragment is maintained by immobilization in a cocked-up pistol-grip position with slight ulnar deviation of the hand.

EPIPHYSIAL SEPARATION. Epiphysial separation at the *lower extremity of the radius* is an extremely frequent injury any time before the twentieth year (Fig. 838). The resulting deformity resembles Colles' fracture, but radial deviation of the hand is not so marked, and reduction is more difficult. There usually is no joint involvement, because the synovial membrane does not reach the level of the epiphysial line. When the separated epiphysis is reduced, the two styloid processes maintain their normal relations, and there is little if any deviation of the distal articular surface of the radius. Many injuries described as Colles' fracture probably are epiphysial separations.

Separation of the *distal epiphysis of the ulna* is rare, because the radius bears the brunt of falls upon the hand. Since most of the growth of the ulna is from the inferior epiphysial line, it is important that this injury be recognized and corrected.

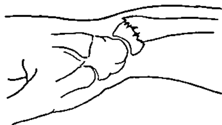


Fig. 837. REVERSED COLLES' FRACTURE, OR SMITH'S FRACTURE.

The fracture occurs with the wrist in flexion; the distal fragment is displaced volarward, and the proximal fragment projects dorsally.

DISLOCATIONS AT THE RADIOCARPAL AND INFERIOR RADIO-ULNAR JOINTS. *Dislocation at the radiocarpal joint* is rare, because the violent shocks transmitted from the hand to the wrist are diffused throughout the carpal joints and because the anterior ligaments at the wrist joint are strong. Many supposed dislocations are fractures of the radius. True dislocation, however, does occur from great violence, and the inferior ends of the radius and ulna may protrude on the dorsal or volar surface of the wrist (Fig. 835).

In dorsal dislocation of the carpus the de-

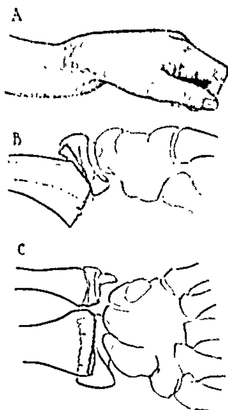


Fig. 838. EPIPHYSIAL SEPARATION OF THE RADIUS WITH DORSAL DISPLACEMENT OF THE EPIPHYSIS.

A, The silver-fork deformity simulating Colles' fracture; *B*, sketch of the roentgenographic finding in lateral view; C, sketch of an anteroposterior roentgenographic view.

formity resembles that of Colles' fracture, except that the palmar swelling in radiocarpal dislocation extends farther down the hand, because the displacement occurs at the radiocarpal joint rather than at some point above it. In dislocation the dorsal bulb has an abrupt upper edge which is not present in fracture, and both styloid processes remain attached to their shafts.

Anterior dislocation of the carpus may occur from trauma, but usually is the result of disease about the wrist. Both the radius and ulna become prominent on the dorsal surface of the wrist with associated depression over the volar surface of the forearm just above the hand.

Dislocation of the ulna at the inferior radioulnar joint may be anterior or posterior, but more commonly is posterior. Neither form is seen commonly except with fracture of the radius. The articular disk and the ulnar collateral ligament usually remain attached to the ulna, which projects markedly on the dorsum of the wrist (Madelung's deformity). Early reduction of the dislocation usually can be accomplished by direct pressure on the epiphysis and rotation of the hand under traction, as in reduction of dislocation of the radiocarpal joint.

CARPAL INJURIES. The force of a fall upon the palm is directed mainly through the third metacarpal to the capitate bone and thence to the navicular and lunate; it causes a variety of injuries to the carpus. Whether a fracture of the navicular (Fig. 839) or a dislocation of the lunate is sustained, depends largely upon whether the extended hand is held in radial or ulnar flexion. With the hand in radial flexion the navicular is brought into a position directly under the radius and is fractured by the direct impact of the capitate. In ulnar flexion all but the proximal part of the navicular glides out of the way, and the lunate is exposed to trauma between the radius and the capitate. The other bones occasionally are fractured, and the capitate sometimes is dislocated dorsally.

Radiography has made possible the recognition of these injuries, which are potential of great disability. When a wrist, after a definite history of trauma, fails to function properly, roentgenographic examination often reveals evidences of old carpal fracture or dislocation. If injury to a carpal bone or a fragment thereof cuts off the blood supply

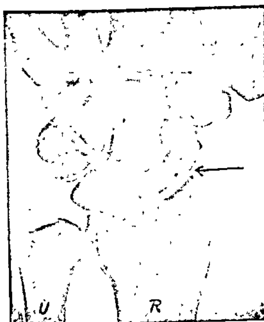


Fig. 839. TRANSVERSE FRACTURE OF THE NAVICULAR BONE.

The arrow points to the fracture line. (From Scudder: Treatment of Fractures.)

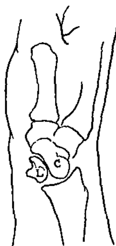


Fig. 840. ANTERIOR DISLOCATION OF THE LUNATE (SEMILUNAR) BONE.

The capitate (os magnum) lies almost against the articular surface of the radius.

entering through the periosteocapsular cuff, the bone dies. The bone may become revascularized or undergo cystic degeneration (Kienböck's disease).

In *fracture of the navicular* the tubercle to which the radial collateral ligament is attached may be torn away. If the bone lies in the articular concavity of the radius at the time of impact, a compression fracture may result. If the hand is in forced dorsiflexion and radial deviation, the distal part of the navicular is driven against the radius by the greater multangular. At the same time the capitate thrusts the proximal end of the navicular against the radius, and the combined result of the two pressures is a transverse fracture beginning at the convexity of the navicular. This fracture may not be immediately recognized by roentgenogram, and a sprained wrist must be treated as a fracture of the navicular with plaster cast fixation until definite roentgenographic proof can be obtained that a fracture is not present. A repeat roentgenogram in two weeks, with the hand held in ulnar deviation, will show the fracture if one is present, because of the absorption about the fracture site that marks the initial healing phase.

Lunate (semilunar) dislocation occurs because the bone is the least securely anchored of all those of the carpal mosaic (Fig. 840). The ligaments binding the lunate to the radius are its strongest attachment; therefore dislocation usually takes place through its weaker carpal attachments. The dislocation occurs with the hand in forced extension, and usually is forward. The notch on the distal surface of the lunate lodges the capitate. When the lunate is in an anterior luxation, a lateral roentgenogram shows it to be volar to the capitate, with its saddle concavity or crescent shadow plainly visible. The direction of the concavity determines the degree of lunate rotation. Not only is bone circulation disturbed by the periosteal injury resulting from the displacement forward into the carpal canal, but the median nerve is compressed. A dislocation of the lunate rarely can be reduced and maintained in reduction by the closed method. It is far better to remove or replace it through a volar median incision.

TUBERCULOSIS OF THE CARPAL BONES. Tuberculosis of the carpus often is extensive and interferes with or abolishes the movements of the wrist and hand. It often begins in the carpus and spreads rapidly throughout the carpal joints (Fig. 841). Occasionally, although rarely, it extends to the radiocarpal joint through a deficiency in one of the interosseous ligaments connecting the proximal row of carpal bones. In an advanced stage of the disease the carpal bones are carious, the articular spaces are occupied by granulation tissue, and the ligaments of the joint soften and relax. Because of their proximity to the diseased parts, the sheaths of the flexor and extensor tendons are frequently involved. The result is an invading tenosynovitis in which masses of granulation tissue distend the sheaths and surround the tendons completely. The wrist and metacarpus are swollen until the normal landmarks disappear. The tapering and stiffened fingers and wasted forearm give the diseased area a characteristic spindle-shaped outline. When suppuration becomes established, sinuses may appear upon the dorsum of the wrist.

Excision of the wrist removes the tuberculous areas. The carpus, the lower articular extremities of the radius and ulna, and the proximal extremities of the metacarpal bones are removed. Removal of all the affected tissues is difficult because of the number of bones and



Fig. 841. TUBERCULOSIS OF THE CARPAL AND WRIST JOINTS.

joints involved and the danger of injuring the important vessels, nerves and tendons surrounding them. Interference with the tendon sheaths may cause stiffness, loss of power, and pain in the hand.

Excellent drainage for suppuration in the radiocarpal joint is established by *ulnar incision* into the joint along the extensor carpi ulnaris tendon. Maintenance of the hand in the semiprone position allows dependent drainage.

APPROACHES TO THE WRIST JOINT. Both the anterior (Fig. 842) and posterior (Fig. 843) approaches for exposure of the carpal bones are satisfactory. Identification of the individual bones is confusing at times, however, and accurate orientation in the operating room, with the aid of a roentgenogram, should be required in every case in which a carpal bone is to be excised. The lateral approach to the wrist joint (Fig. 844) gives excellent exposure of the navicular and the greater multangular. The medial approach is made directly over the lower end of the ulna and upper end of the fifth metacarpal. There are no intervening structures except the fasciae. Care should be taken

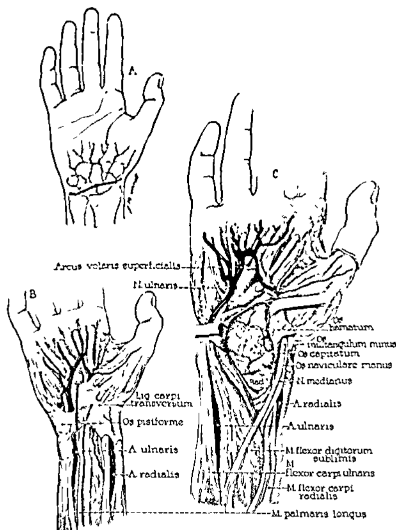


Fig. 842. TRANSVERSE ANTERIOR OR VOLAR APPROACH TO THE WRIST JOINT.

A, Transverse incision in the distal flexor crease of the wrist. The longitudinal incision crossing the flexion crease is much less desirable because of its tendency to contract later. The superficial and deep fasciae are incised transversely and retracted. *B*, The palmaris longus tendon is identified, and the median nerve found lying deep to it and a little radialward. The line of incision through the transverse carpal ligament is shown. *C*, Transverse carpal ligament incised. The median nerve and the tendons of the palmaris longus and flexor pollicis longus muscles (lying deep to the flexor carpi radialis) are retracted to the radial side. To the ulnar side go the flexor digitorum sublimis and profundus tendons. Dividing the joint capsule exposes the lower end of the radius and the carpal bones The amount of retraction and exposure depends upon the surgical problem.

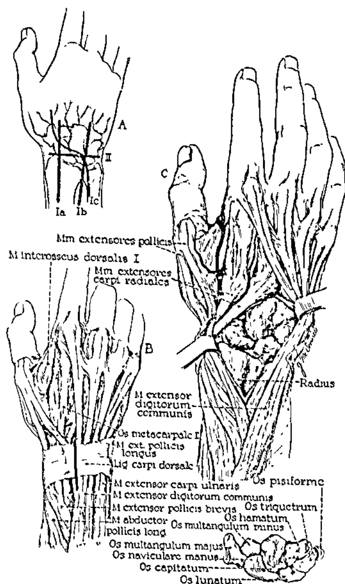


Fig. 843. POSTERIOR APPROACHES TO THE WRIST.

A, Three-inch longitudinal incision may be made on either side (*Ia* and *Ib*), depending upon the bones to be exposed; *Ic*, a curved incision permits good exposure for wrist fusion, tendon repair or removal of multiple carpal bones, and minimizes the danger of postoperative contracture. A transverse incision in the skin creases (*II*) somewhat limits the exposure, but is a satisfactory approach to one or 2 of the carpals.

B, The superficial and deep fascia are divided either longitudinally or transversely, depending upon the skin incision, and the dorsal carpal ligament is incised longitudinally between the extensor pollicis longus and extensor digitorum communis. *C*, Good retraction and incision of the articular capsule expose the dorsal surface of the radius and the carpal bones. Obviously, the approach and the retraction will be modified to fit the particular surgical problem.

not to injure the intra-articular fibrocartilage, which is attached to the styloid process of the ulna. With proper selection of these incisions and adequate retraction, all operations on the wrist joint can be carried out.

Arthrodesis of the Wrist. An arthrodesis, or operative production of a bony ankylosis, is indicated for a flail wrist, for ankylosis of the wrist in faulty position, for paralytic wrist drop and for some arthritic conditions. Thirty degrees' extension with ulnar deviation is the functional position for the hand, since the flexors and extensors of the wrist are in muscle equilibrium in this position.

Through a dorsal incision the tendons and the capsule with its reinforcing dorsal ligament are exposed. The capsule is incised longitudinally and stripped from the insertion on the forearm bones until these bones and the proximal row of carpal bones are exposed. A wedge is removed from the radius and from the ad-

joining portions of the navicular and lunate bones. The wedge is of sufficient size to permit the hand being fixed in 25 to 30 degrees of extension (Fig. 845). Radical carpal arthrodesis does not eliminate motion in the carpus, since the movement between the proximal and distal rows of carpal bones is not disturbed. Pronation and supination are sacrificed.

DISARTICULATION THROUGH THE RADIOCARPAL JOINT. Disarticulation through the radiocarpal joint is rarely performed, because it gives an unsatisfactory stump from both the surgical and prosthetic standpoints. The stump end is irregular, and both styloid processes are prominent and sensitive. The skin covering is thin, and its circulation is poor. The stump is more difficult to fit than one low in the forearm, and a prosthesis tends to make the extremity longer than normal. Pronation and supination are retained in radiocarpal disarticulation, but few prostheses make use of this function. If disarticulation at the radiocarpal level is selected, both styloid processes should be removed, and the radius and ulna should be rounded. The base of the radial styloid should be preserved to save the attachment of the brachiora-

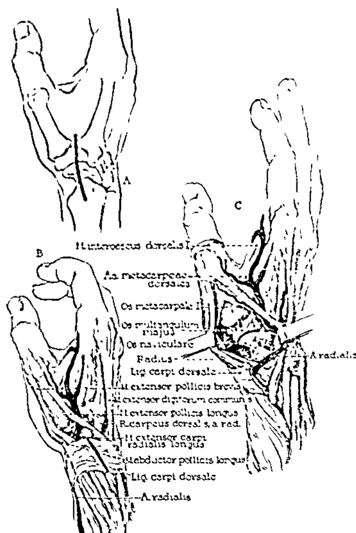


Fig. 844. LATERAL APPROACH TO THE WRIST JOINT.

A and *B*, A slightly curved 2-inch radial incision, centered over the navicular, is made between the tendons of the extensor pollicis longus and brevis muscles. *C*, The deep fascia and dorsal carpal ligament are divided. The extensor pollicis brevis tendon and abductor tendons of the thumb are retracted to the palmar side. The extensor pollicis longus tendon and the radial artery are retracted dorsally. If it suits better, the radial artery can go to the palmar side, but it must be carefully protected either way. The joint capsule is then divided longitudinally, exposing the lateral aspect of the wrist joint.

This approach is used for open reduction of an un-united fracture of the carpal navicular.

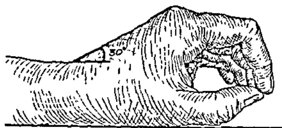


Fig. 845. OPTIMUM POSITION FOR ANKYLOSIS OF THE WRIST.

dialis tendon, which aids materially in supination and flexion of the forearm. A long palmar flap brings portions of the short muscles of the thenar and hypothenar eminences over the stump, and the line of closure is on the dorsal aspect of the stump. As these tissues are very vascular, they bear pressure well. Circular amputation has the disadvantage of causing a terminal scar and of forming only a scant covering for the bones.

DISARTICULATION AT THE CARPOMETACARPAL JOINT. The carpus makes a fairly functional stump when covered with healthy skin and subcutaneous tissue from a long, convex palmar flap. When the flexor and extensor tendons are sutured into the stump, a good range of motion is obtained.

The skin incision for the palmar flap begins 1 cm. below the radial styloid and extends down the palmar surface of the hand along the line of the second metacarpal nearly to the middle of the palm, gradually swinging across the palm to its middle. Another skin incision begins 1 cm. below the ulnar styloid, and extends down the palmar surface of the hand along the fifth metacarpal to meet the radial incision in the middle of the palm. A straight dorsal incision, or an incision with a slight proximal convexity, is made across the carpus to form the short dorsal flap. The incision is deepened to the bone. The long palmar flap composed of skin and palmar fascia is dissected back to the carpometacarpal joint. The flexor tendons are cut long and are freed from the carpometacarpal joint on the palmar aspect. The dorsal extensor tendons which have been cut are secured to the carpus to prevent retraction. The metacarpals are disarticulated from their carpal attachments. The median, ulnar and radial nerves are secured, ligated, and injected with absolute alcohol before they are allowed to retract. A sufficient number of the flexor and extensor tendons are sutured into the periosteocapsular tissue of the stump to assure flexion and extension. A palmar cock-up splint prevents palmar flexion at the radiocarpal joint.

If the amputation includes the bases of the metacarpals, suture of the flexor and extensor tendons into the stump is not necessary, since the carpal flexors and extensors inserting into the metacarpal bases control the stump and give good power.

CHAPTER 32

The Hand

The hand is an organ of prehension and exquisite sensibility. The sensory function is dependent upon the fact that the terminals of the digital nerves are connected with specialized end-organs (tactile corpuscles) in the papillary layer of the skin. These end-organs are developed particularly well over the palm and volar aspect of the terminal phalanges. Tactile sensibility probably is keenest at the extremities of the fingers. In the blind, who judge objects by touch, tactile sensibility attains a remarkable acuity and, in a considerable measure, compensates for the loss of sight.

The prehensile function is dependent upon the fact that the hand modifies its shape and strength of action to suit the conformation and consistency of the object grasped, like a marvelously adapted pair of forceps. The thumb, with its strong, mobile metacarpal, forms one blade of the forceps, and the remaining fingers, individually or collectively, form the other. The property of apposition cannot be overestimated, for the functional capacity of the hand depends largely upon the integrity of the thumb. Viewed mechanically, a hand deprived of the thumb is little more than a hook, and loses its usefulness to a degree out of all proportion to that which results from the loss of any of the other digits. In injury or disease of this digit, effort should be made to preserve it entirely, or as much of it as is possible.

The hand, directed by the will and guided in a large measure by the eyes, can perform a great variety of delicate and complicated movements through the highly coordinated action of its extrinsic and intrinsic muscles and its complicated system of joints. This is witnessed in the marvelous dexterity acquired by musicians, magicians and skilled mechanics.

The hand is divided into palmar (Fig. 846), dorsal (Fig. 860) and phalangeal regions.

Palmar Region

The palm is roughly quadrilateral in outline, and comprises all the soft parts in front of the metacarpal bones and the volar interosseous muscles. The triangular central part is depressed into the "hollow of the hand" and is bounded on each side by a well defined projection of muscle. That on the radial side, the thenar eminence, formed by the short muscles of the thumb, and that on the ulnar side, the hypothenar eminence, formed by the short muscles of the little finger, approximate each other as they approach the wrist. Their line of junction is indicated by a shallow median groove which leads across the wrist toward the tendon of the palmaris longus.

SURFACE ANATOMY. The *superficial palmar arch* lies at the level of the deep transverse crease made by metacarpophalangeal flexion. The common volar digital arteries emerge from this arch and divide into their proper digital arteries about 1 cm. proximal to the webs of the fingers. The *deep palmar arch* lies about 2 cm. nearer the wrist than the superficial arch, and its center corresponds fairly closely with the apex of the hollow of the hand.

With the fingers in complete extension a series of shallow longitudinal *grooves* extend from the roots of the fingers toward the palm, with the intervals between the furrows occupied by raised areas in the skin. The furrows correspond to the digital slips of palmar fascia which overlie the flexor tendons, and the intervening prominences or masses of fatty tissue are smoothed out when the tendons are stretched. Within the projections of tissue the digital vessels, nerves and lumbrical muscles are directed toward the webs of the fingers.

The metacarpophalangeal joints are located fairly accurately on a line 2 cm. proximal to the webs of the fingers.

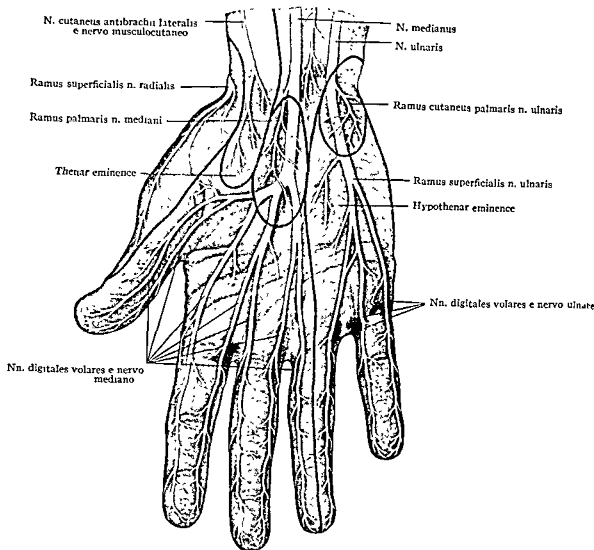


Fig. 846. SURFACE ANATOMY AND AREAS OF CUTANEOUS NERVE SUPPLY OF THE PALMAR REGION.

SUPERFICIAL STRUCTURES. The skin over the thenar eminence is thinner than that over the heads of the metacarpal bones and that of the hypothenar eminence. Over the central areas of the palm the skin is rendered extremely tight and resistant by fibrous septa which bind it to the palmar aponeurosis (deep palmar fascia). These septa are a distinctive feature of the subcutaneous tissue in this region. The close connection between the skin and the resistant palmar fascia enables the center of the palm to withstand great pressure. For the same reason, pus cannot accumulate in any quantity superficial to the palmar fascia, but makes its way upward through the skin and collects under the epidermis.

PALMAR APONEUROSIS. The palmar aponeurosis (deep fascia) consists of a strong central portion and two weaker lateral portions which overlie the thenar and hypothenar eminences (Fig. 848). The central portion, or palmar aponeurosis proper, is an exceedingly dense, white ligamentous structure which prevents the outward spread of pus or blood. The longitudinal fibers are most numerous and are derived from the tendon of the palmaris longus muscle. From the radial and ulnar margins, fibrous septa pass backward to wall off the muscles of the thenar and hypothenar eminences. Proximally, the aponeurosis blends with the transverse carpal ligament (Fig. 848); distally, it widens out and divides into four slips at the level of the head of the inner four metacarpal bones. These slips blend with the corresponding fibrous digital sheaths and lateral ligaments of the metacarpophalangeal joints and insert into the sides of the bases of the proximal phalanges, which they assist in

flexing. The digital arteries and nerves lie between these slips *en route* to the webs of the fingers (Fig. 848).

All the superficial lymph vessels of the fingers and palm, save a few running up the front of the forearm, pass to the dorsum of the hand, where they become associated with the superficial veins. These vessels are joined by the deep lymph vessels of the palm, an arrangement which explains the frequency of edema and metastatic infection on the dorsum of the hand from infection of the fingers and palm.

Palmar Muscles. The palm contains not only the tendons of the superficial and deep flexor muscles of the fingers which descend into it from the anterior surface of the forearm, but also three intrinsic groups of short muscles (Figs. 848, 849). The external group embraces the thumb muscles and forms the thenar eminence; the internal group is composed of the muscles of the little finger and forms the hypothenar eminence; and the middle group consists of the lumbrical muscles.

The *thenar eminence* has four muscles, the abductor pollicis brevis, flexor pollicis brevis,



Fig. 847. TESTS FOR THE ACTION OF THE MUSCLES OF THE THENAR EMINENCE AND OF THE INTEROSSEI AS EVIDENCE OF INTEGRITY OF THE MEDIAN AND ULNAR NERVES.

(Modified from MacGregor.)

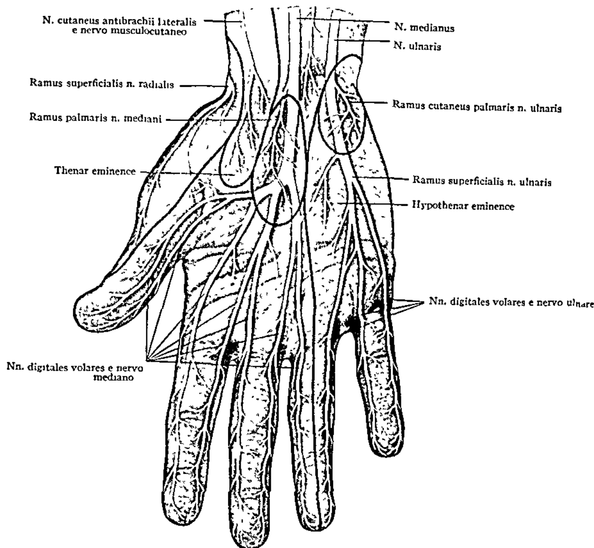


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tion of rotating the thumb opposite the other fingers in the pincer action of picking up objects (Fig. 847).

The *hypothenar eminence* is made up of the abductor, opponens, and flexor digiti quinti brevis muscles, all of which are supplied by the deep branch of the ulnar nerve (C 8; T 1). When an abscess forms in that area, which is shut off from the central space of the palm by the fibrous partition passing dorsally from the ulnar side of the palmar aponeurosis, the infection points readily on the surface of the eminence. Incision for draining the abscess is made at the ulnar side of the fifth metacarpal, dorsal to the pisiform. This approach does not endanger the digital branches of the superficial volar arch and the ulnar nerve, which run distally in front of the flexor digiti quinti brevis muscle to the ulnar side of the small finger (Fig. 849).

The four long, thin *lumbrical* (Latin, = earthworm) *muscles* arise from the tendons of the flexor digitorum profundus in the palm, and are inserted into the radial side of the fibrous expansions of the long extensor tendons and the adjoining parts of the proximal phalanges of the medial four digits. They flex the fingers at the metacarpophalangeal joints, but extend them at the interphalangeal joints through the extensor expansions. The lumbrical muscles of the small and ring fingers are supplied by the deep branch of the ulnar nerve, and those of the index and middle fingers by the median nerve.

Arteries of the Palm. The radial and *ulnar arteries form two anastomotic arches*

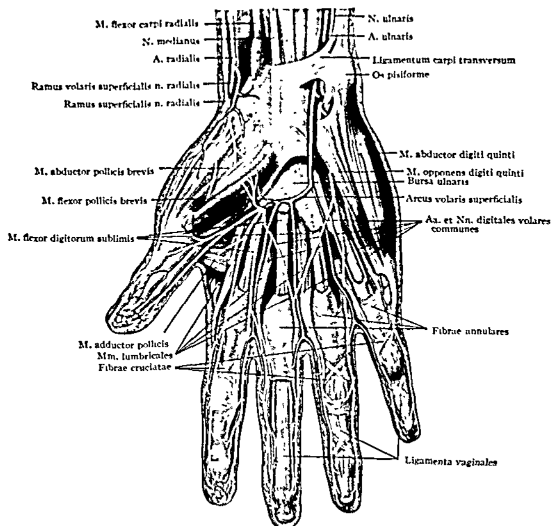


Fig. 849. STRUCTURES OF THE PALM AFTER REMOVAL OF THE PALMAR APONEUROSIS.

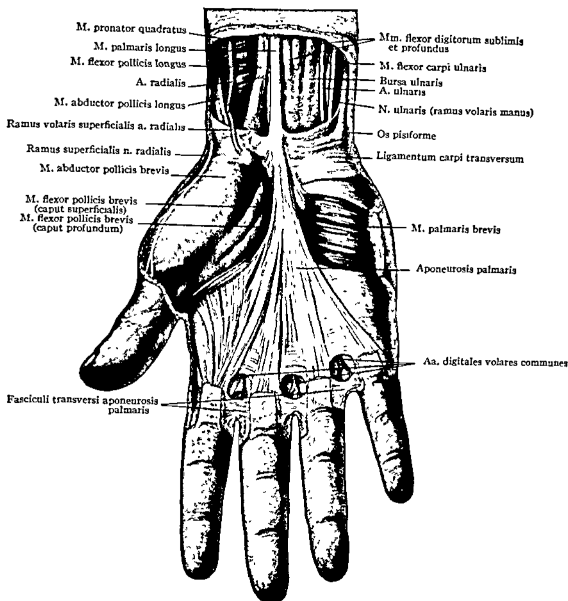


Fig. 848. SUPERFICIAL STRUCTURES OF THE WRIST AND PALMAR REGIONS.

opponens pollicis and adductor pollicis. The first three muscles lie at the radial side of the tendon of the flexor pollicis longus, and all are supplied by the median nerve (C 8; T 1). They lie in a separate compartment shut off from the central space of the palm by a fascial sheet that passes dorsally from the radial margin of the central division of the palmar aponeurosis. When pus forms among these muscles, it is localized definitely and manifests no tendency to spread backward or medially. Incision for drainage should be made over the distal part of the first metacarpal on the radial side of the eminence in order to avoid the nerve supply which enters the eminence mesially. The adductor pollicis (N. ulnar, C 8; T 1) is a fan-shaped muscle which lies in the depth of the palm and has an oblique and a transverse head. Its base is attached to the third metacarpal and its apex to the base of the first phalanx of the thumb. It has considerable surgical importance as the floor of the thenar fascial space (p. 902). By its oblique and transverse heads it draws the thumb across the palm in a plane parallel to the palm. The abductor pollicis brevis pulls the thumb directly forward from the palm in a plane at a right angle to the palm. The opponens pollicis enables the pad of the terminal phalanx of the thumb to be placed against that of any other finger. The abductor pollicis brevis and the opponens together are responsible for the ac-

and its branches. Between the deep flexor tendons and the fascia over the interossei are potential fascial spaces where palmar infections sometimes localize (p. 902). Under the fascia covering the interosseous muscles lie the deep palmar arch and the deep division of the ulnar nerve.

FLEXOR TENDONS AND THEIR PALMAR SYNOVIAL SHEATHS. The FLEXOR TENDONS passing beneath the transverse carpal ligament are provided with two synovial sheaths, one for the flexor pollicis longus muscle and the other for the closely grouped tendons of the flexor digitorum sublimis and profundus muscles (Fig. 850). These synovial investments are arranged in a somewhat complicated manner (Fig. 851).

The synovial sheath for the tendon of the flexor pollicis longus extends distally to the insertion of the tendon and proximally to a point two fingerbreadths proximal to the upper margin of the transverse carpal ligament. This sheath sometimes is known as the RADIAL BURSA because of its upward extension into the distal part of the radial side of the forearm. It is made up of a visceral layer which closely invests the tendon, and a parietal layer which lines the wall of the cavity in which the tendon plays. The arrangement is one which would obtain if the tendon were invaginated into the side of a cylindrical synovial tube with a mesotendon through the entire length of the sheath. The mesotendon degenerates in places, but persists as the vinculum breve and vinculum longum. The first vinculum is a triangular fold attaching the terminal part of the tendon to the floor of the synovial cavity, and the second connects the tendon and floor at several more proximal levels. Between the levels of mesotendon attachment, the synovia-covered tendon lies free.

In the wrist and palm the synovia for the flexor digitorum sublimis and profundus tendons forms a common sheath, the ULNAR BURSA, which extends proximally as far as does the bursa for the flexor pollicis longus muscle (Figs. 851, 853). Distally, the limit is oblique, and reaches a lower level on the ulnar than on

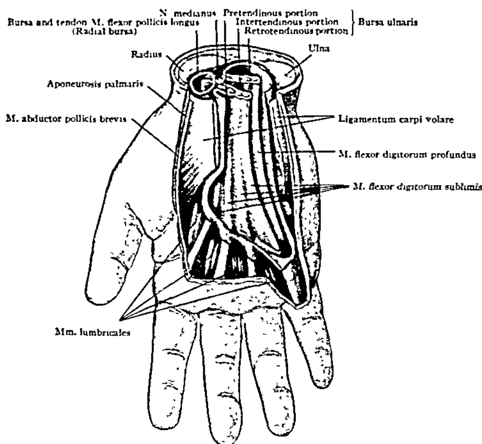


Fig. 850. DIAGRAM OF THE ARRANGEMENT OF THE RADIAL AND ULNAR BURSAE IN THE WRIST AND PALM.

in the palm from which the terminal digital arteries are distributed (Fig. 849). The *superficial volar (palmar) arch* is the palmar continuation of the ulnar artery, which enters the palm on the radial side of the ulnar nerve, and lies just to the radial side of the pisiform and the hook of the hamate (unciform). It runs obliquely, distally and laterally to reach the midpoint of the palm in relation to the proximal transverse crease, and describes a variable curve toward the web of the thumb, where it lies deep to the palmar fascia. It crosses immediately in front of the flexor tendons and their sheaths and the digital branches of the median nerve. The arch varies in its mode of termination, but typically is joined by a superficial branch of the radial artery (superficial volar princeps pollicis or radialis indicis).

The arch gives off four palmar digital branches, one to the ulnar side of the little finger and the other three in the second, third and fourth intermetacarpal spaces, to the webs of the fingers. In their course they overlie the second, third and fourth lumbrical muscles and often receive communicating branches from the deep arch. About 1 cm. proximal to the web, each artery divides into collateral digital branches which run along the palmar sides of the adjacent fingers.

The deep branch of the ulnar artery, given off in the wrist, enters the palm to supply the hypothenar eminence and, with the main trunk of the radial artery, forms the *deep volar (palmar) arch*. On leaving the wrist the radial artery winds about the radial side of the radial collateral ligament, and enters the palm between the bases of the metacarpals of the thumb and the index finger at the proximal end of the first interosseous space. From its position between the transverse and oblique heads of the adductor pollicis muscle it passes forward across the palm to the fifth metacarpal, where it receives the deep branch from the ulnar artery to form the deep volar (palmar) arch. The arch lies deep to the flexor tendons and their palmar synovial sheaths on the volar interosseous muscles and the bases of the metacarpal bones. If hemorrhage from the arch cannot be controlled by pressure, recourse may be had to ligation of the radial and ulnar arteries. The circulation is re-established by the volar and dorsal interosseous arteries. From the deep arch, branches are given off proximally to the arterial network about the wrist (volar carpal arch), and metacarpal branches are given off distally to join the digital arteries.

NERVES OF THE PALM. The *median nerve* enters the palm deep to the transverse carpal (anterior annular) ligament, where it lies upon the flexor tendons (Fig. 849). At the lower border of the ligament it breaks up into lateral and medial terminal divisions. The lateral division at once supplies the thenar muscles and gives off digital branches to both sides of the thumb and the radial side of the index finger. It also supplies the first lumbrical and second, or lateral lumbrical muscles. The medial terminal division supplies the cleft between the index and middle fingers and between the middle and ring fingers.

The *ulnar nerve* pierces the deep fascia at the wrist and crosses the transverse carpal ligament immediately at the radial border of the pisiform bone (Fig. 849). It divides into superficial and deep branches opposite the hook of the hamate (unciform). The superficial branches of the nerve supply digital branches to the little finger and to the ulnar side of the ring finger. The deep branch of the nerve is accompanied by the deep branch of the ulnar artery. It supplies the short muscles of the little finger and the two inner lumbricals. All the interosseous muscles, the adductor pollicis, and part of the flexor pollicis brevis undergo atrophy after section of the ulnar nerve (p. 919). This nerve supplies most of the small muscles of the hand, and therefore is mainly responsible for most of the fine movements of the hand. Hence it has been called "the musician's nerve." The lumbricals once were known as the "fiddler's muscles."

CENTRAL COMPARTMENT OF THE PALM. The central compartment of the palm is bounded superficially by the palmar aponeurosis and deeply by the aponeurosis which invests the interosseous muscles. Laterally, the compartment is shut off from the thenar and hypothenar eminences by the union of the two aponeuroses. The compartment narrows proximally, where it becomes continuous with the carpal canal under the transverse carpal ligament (Fig. 849). It widens out below and continues along the flexor tendon sheaths into the subcutaneous stratum of the fingers.

The central portion of the palm contains the lumbrical sheaths, the superficial volar arch and its branches, and the median nerve

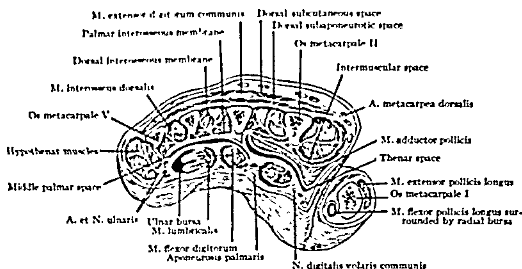


Fig. 852. CROSS SECTION THROUGH THE RIGHT HAND TO SHOW THE FASCIAL SPACES IN THE ANTERIOR AND POSTERIOR REGIONS OF THE HAND; ALSO THE RADIAL AND ULNAR SYNOVIAL BURSAE.

(After Kanavel.)

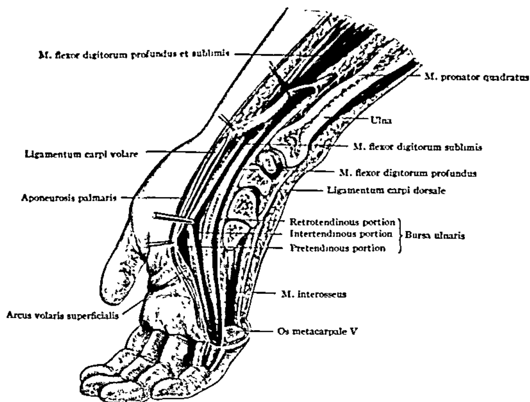


Fig. 853. LONGITUDINAL SECTION THROUGH THE HAND, WRIST AND LOWER FOREARM TO SHOW THE EXTENT AND DIVISIONS OF THE ULNAR SYNOVIAL BURSA.

Attention is called to the carpal and antebrachial divisions of the common palmar sheath (ulnar bursa); this drawing explains the rationale of draining all the pouches of the ulnar bursa through an incision on the ulnar aspect of the palm. (After Kanavel.)

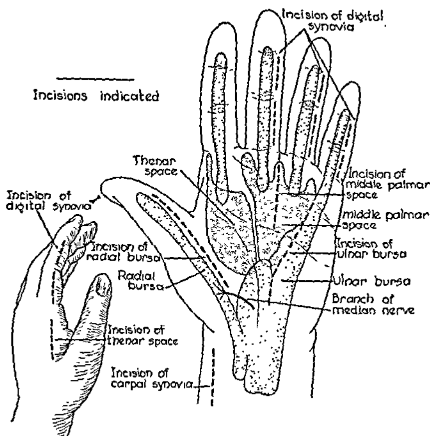


Fig. 851. LOCATION OF DIGITAL, PALMAR AND CARPAL SYNOVIA, AND OF FASCIAL SPACES OF THE HAND. Surgical paths of approach to these structures are indicated. (Modified from Kanavel and Mason.)

the radial side. The part of the sheath nearest the ulnar runs distally over the tendons of the little finger to their insertion.

From a transverse section through the proximal part of the palm it is evident that the tendons of the superficial and deep flexor muscles have invaginated the common sheath from the side nearest the thumb, so as to subdivide it into three pouches, all of which intercommunicate freely at the ulnar side of the sheath (Fig. 850). That division of the ulnar bursa between the four sublimis tendons and the volar aponeurosis (palmar fascia) is the *pretendinous pouch;* that between the sublimis and profundus tendons is the *intertendinous pouch.* The deepest carpal division, that between the profundus tendons, the floor of the carpal canal, and the floor of the central compartment of the palm, is the *retrotendinous pouch.* The prolongations of the ulnar bursa which correspond to the tendons of the index, middle and ring fingers do not extend beyond the middle of the palm. The prolongation of the tendons of the little finger, as a rule, reaches the base of the terminal phalanx.

Several variations in the sheaths are noteworthy. The flexor pollicis longus sheath sometimes is in two separate parts, palmar and digital. The sheath for the flexor pollicis longus frequently communicates freely with the common palmar sheath. The index tendon of the profundus sometimes has a palmar sheath. The digital sheath of the small finger frequently fails to communicate with the common sheath (Fig. 864).

A *compound palmar* GANGLION is a tuberculous synovitis of the common palmar sheath. It causes an hourglass swelling extending from the distal part of the forearm into the palm, with the constriction at the transverse carpal ligament. The entire sheath may have to be excised, a procedure usually resulting in damage to the flexor tendons and the median and ulnar nerves.

The *median nerve* lies between the sheath of the flexor pollicis longus (radial bursa) and the common palmar sheath (ulnar bursa). Between the common palmar sheath and the palmar aponeurosis is a fatty areolar layer in which lies the superficial volar arch. *Between*

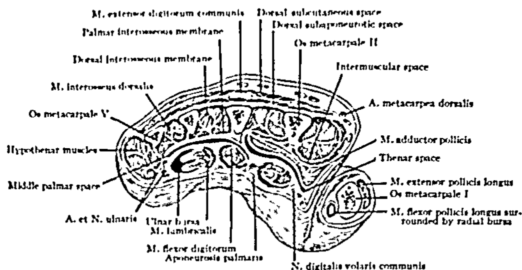


Fig. 852. CROSS SECTION THROUGH THE RIGHT HAND TO SHOW THE FASCIAL SPACES IN THE ANTERIOR AND POSTERIOR REGIONS OF THE HAND; ALSO THE RADIAL AND ULNAR SYNOVIAL BURSAE.
(After Kanavel.)

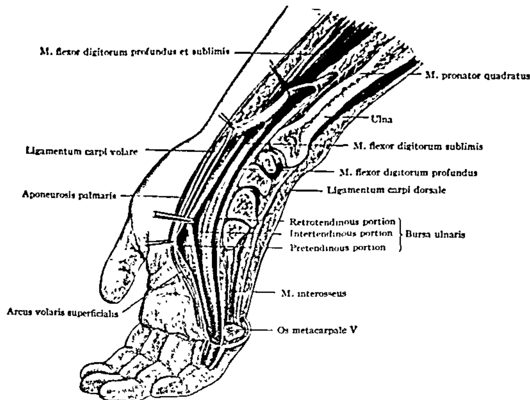


Fig. 853. LONGITUDINAL SECTION THROUGH THE HAND, WRIST AND LOWER FOREARM TO SHOW THE EXTENT AND DIVISIONS OF THE ULNAR SYNOVIAL BURSA.

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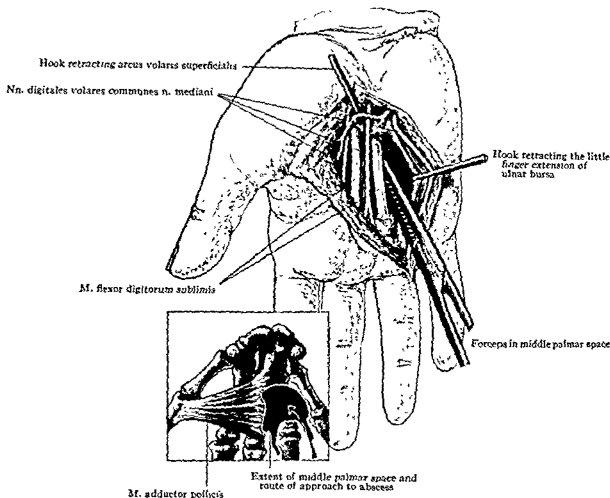


Fig. 854. DISSECTION OF THE STRUCTURES ABOUT THE MIDDLE PALMAR SPACE, AND (INSET) THE PATH OF SURGICAL DRAINAGE OF THE SPACE.

(After Kanavel.)

the common sheath and the volar interosseous aponeurosis are the deep fascial spaces of the palm.

DEEP FASCIAL SPACES OF THE PALM AND THEIR MODES OF INFECTION. Deep to the flexor tendons and the lumbrical muscles is a large fascial space which is divided into midpalmar and thenar spaces by a fibrous septum attached along the shaft of the middle metacarpal bone (Figs. 851, 852). This partition usually is strong enough to prevent the spread of pus from one space to the other.

The *middle palmar space* lies between the middle metacarpal bone and the radial side of the hypothenar eminence, from which it is separated completely by a fibrous partition. Its dorsal boundary is the volar interosseous aponeurosis, which covers the volar interossei in the third and fourth intermetacarpal spaces. It is bounded anteriorly by the tendons of the little, ring and middle fingers and their lumbrical muscles (Fig. 852). This space may be infected directly by puncture wounds or by compound fractures of the third, fourth and fifth metacarpals, or secondarily by superficial infections in the corresponding fingers. It may be involved by the spread of infection from the closed proximal ends of the digital synovial sheaths of the middle and ring fingers. Pus in this space, unless evacuated early, spreads distally along the lumbrical tendons and points at the webs of the fingers. Rarely, it may extend proximally behind the flexor muscles into the forearm.

The *thenar space* is located deep to the tendons of the index finger and the first lumbrical muscle between the middle palmar space and the tendon of the flexor pollicis longus. It is bounded behind by the adductor of the thumb (Fig. 852). Direct infections may result

from puncture wounds or, rarely, compound fracture of the shaft of the second metacarpal. Pus within the space may spread backward between the two heads of the adductor of the thumb or, more usually, over the distal free border of the transverse head to a point on the dorsal surface of the web of the thumb. Rarely, the pus may spread proximally into the forearm or distally into the web between the index and middle fingers.

Surgical Considerations

ROUTES TO THE PALMAR SYNOVIA OF THE ULNAR AND RADIAL BURSAE. An *incision into the common palmar sheath* or *ulnar bursa* extends from the base of the small finger at the distal crease of the palm to the apex of the palm toward the carpal canal. A director may be inserted into the sheath at this point and be carried along its space. To facilitate drainage of the pretendinous, intertendinous and retrotendinous pouches, the tissue between the sheath and skin is incised as far to the ulnar side of the sheath as possible. If infection has reached the transverse carpal ligament, pressure over the forearm prolongation of the sheath forces pus downward into the sheath below the ligament. If forearm involvement is diagnosed, incision low in the forearm is indicated (p. 866). It may be necessary to divide the transverse carpal ligament to avoid the danger of necrosis of the tendons. This should be done as far to the ulnar side as possible.

An *incision into the sheath of the long flexor tendon of the thumb* or *radial bursa* is made on the flexor surface of the proximal phalanx, and is extended upward along the bursa through the margin of the thenar eminence. It should be kept in mind that the tendon lies nearer the hollow of the palm than would be expected, and that therefore the mass of thenar muscles lies to the radial side of the incision. The dissection is carried only to within a thumbbreadth of the lower margin of the transverse carpal ligament, for the branch of the median nerve to the thenar muscles (p. 900) passes across the sheath between this point and the lower edge of the transverse carpal ligament. Damage to the flexor tendon of the thumb is the preferable alternative to destruction of this nerve and paralysis of the short thumb muscles which it supplies. Drainage of the proximal or antebrachial extremity of the radial bursa is best obtained by the method described for evacuation of an abscess in the corresponding location in the ulnar bursa (p. 900).

ROUTES TO THE FASCIAL SPACES OF THE HAND. An *abscess of the middle palmar space* should not be opened upon the ulnar side for

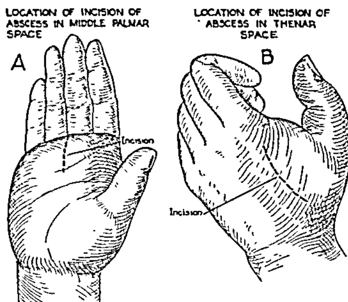


Fig. 855. INFECTIONS IN THE MIDDLE PALMAR AND THENAR SPACES, AND SURGICAL PATHS OF APPROACH.

A, Infection in the middle palmar space; concavity of palm lost; incision to space indicated between middle and ring fingers. *B*, Infection of the thenar space; thenar area ballooned out, and thumb slightly flexed and pushed away from the hand. (Redrawn from Kanavel and Mason.)

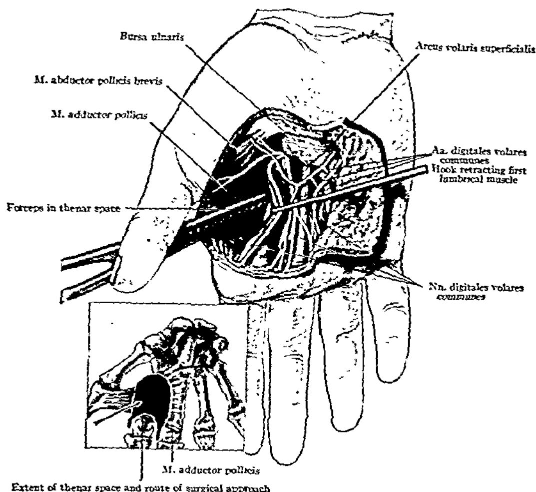


Fig. 856. DISSECTION OF THE STRUCTURES ABOUT THE THENAR SPACE, AND (INSET) THE PATH OF SURGICAL DRAINAGE OF THE SPACE.

The inset is a diagram of an abscess in the thenar space lying on the adductor pollicis muscle. (After Kanavel.)

fear of infecting the common palmar sheath (ulnar bursa) (Fig. 853). The least injury and the most efficient drainage are secured through a web incision along the lumbrical tendon between the small finger and the ring finger (Fig. 854). It is possible also to incise along the lumbrical tendon between the ring finger and the middle finger. The incision between the ring and middle fingers best avoids injury to the ulnar bursa. The incision is carried a thumbbreadth and a half into the palm. An artery clamp thrust beneath the group of flexor tendons affords a path for satisfactory drainage.

In *infection of the thenar space* the pus usually lies anterior to the transverse head of the adductor muscle of the thumb, but may also *lie dorsal to* it. The most readily available incision site is the radial side of the index metacarpal opposite its distal half and on a level with its flexor surface (Figs. 855, 856). A hemostat is thrust into the space across the flexor surface of the index metacarpal. From this location a collection of pus, either in front of or behind the transverse adductor, is entered readily. The hemostat should not be carried beyond the middle metacarpal lest the infection be spread to the middle palmar space.

Collar-Button Abscess. A collar-button abscess is located at the distal edge of the palm under the dermal or epidermal tissues (Fig. 857). Its occurrence in workmen may be attributed to the fact that the distal palmar epidermis becomes hypertrophied into a dense sheet, under which infection spreads. Pus in the subdermal tissue passes through the dermis to the epidermis, where a second division of the abscess forms, producing a collar-button-shaped accumulation of pus. Infection may occur in the epidermis, erode through the dermis, and produce the same condition. When pus accumulates in this manner over the distal

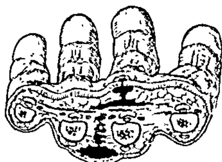


Fig. 857. COLLAR-BUTTON ABSCESS OF THE PALM.

The pus has penetrated through the interosseous muscles to the back of the hand, forming a complicated abscess with three divisions. (After Homans)

end of the palmar aponeurosis, where the sheath may be thin in places, it spreads easily into the web of the finger. When the palmar aponeurosis is deficient, the abscess enters the cellular tissue of the web and points on the dorsum of the hand between the bases of the fingers, forming a complicated abscess in three layers.

LOCALIZED ABSCESS IN THE THENAR AND HYPOTHENAR REGIONS. Within the thenar and hypothenar eminences several minor and indefinite spaces lie beneath the fascia overlying the muscles. Because these spaces are superficial, they are infected by puncture wounds more frequently than are the deeper fascial spaces. A minor infection within the superficial tissues of the thenar or the hypothenar area may be associated with great edema of the dorsum of the hand. This edema may be mistaken for evidence of pus in the palmar spaces. The fascia overlying the eminences localizes infection at the site of implantation. Infection is drained by simple incision.

DUPUYTREN'S CONTRACTURE. Dupuytren's contracture depends upon an insidious, interstitial fibrotic retraction of one or more of the digital slips or processes of the palmar aponeurosis and of the fibrous bands connecting these with the overlying skin. The progressive retraction of these fibers puckers the skin of the palm and the sides of the fingers into an obstinate flexion (Fig. 858). It occurs most frequently in the little and ring fingers, but particularly in the latter, and causes the hand to assume the position of "the Papal benediction." Flexion occurs at the metacarpophalangeal joint. After the fibrosis has involved the weak areas in the fibrous sheaths opposite these joints, the phalanges are flexed slightly. In this deformity further flexion is attainable, but normal extension of the finger on the metacarpus is impossible. With forcible efforts to straighten the finger, the shortened band stands out as a rigid cord beneath the skin, to which it appears to adhere closely. In an advanced contracture the dense fibrous cord passes downward from the center of the palm to the level of the base of the proximal phalanx of the contracted finger, and has been found in dissected specimens to have attachments to the periosteum of the lateral aspects of the phalanx.

In the way of treatment Michael Mason* states that the surgeon cannot predict the course which a given contracture will take. The nodule may cause few or no symptoms, and if no contracting bands develop, the patient may not be disabled in any way by the disease. Operative intervention can scarcely be urged at this stage. However, if disability is present or if the process is growing, it is advisable to operate, and then the procedure should consist in complete removal of the fascia (Fig. 859). Only in exceptional cases would it seem that partial procedures are indicated. Subcutaneous fasciotomy is hazardous in view of the intricate anatomic relation of the contracted fascia to nerves and blood vessels in the distal palm and fingers. The incidence of recurrence is likewise higher with subcutaneous fasciotomy.

* Arch. Surg., 65: 457-63, 1952.

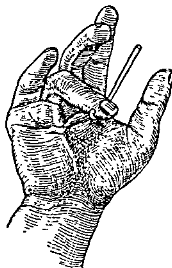


Fig. 858. DUPUYTREN'S CONTRACTURE.

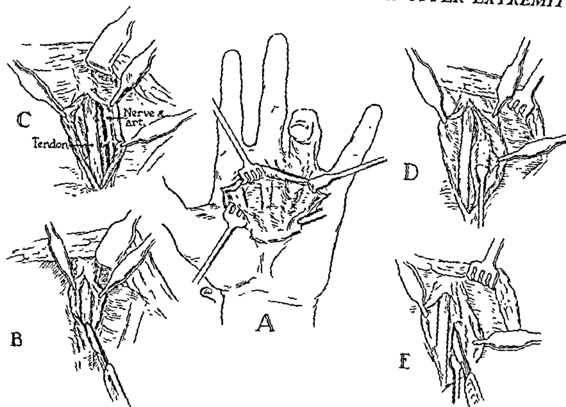


Fig. 859. COMPLETE EXCISION OF FASCIA FOR DUPUYTREN'S CONTRACTURE.

The palmar fascia is uncovered through a transverse incision in the palm and usually by a second incision skirting the thenar eminence. *A*, The base of the fascia is divided where it takes origin from the transverse carpal ligament, and drawn distally. Distal to the superficial volar arch, the deep vertical sheets of fascia hold the palmar plate securely attached to the deep palmar fascia. These sheets likewise contain the neurovascular bundles. In order to visualize these sheets, the pretendinous bands are divided longitudinally so as to come down upon the underlying tendons. *B*, When the halves of the band are drawn aside, the nerves and vessels may usually be visualized, covered by a layer of fascia (*C*). A spatula used as a retractor is then introduced beneath the vertical sheet, and the surgeon may then divide this layer close to its attachment to the deep palmar fascia (*D* and *E*). By following cautiously along distally the surgeon can keep the nerves and vessels under constant visual control. (From Mason: Arch. Surg., 65: 457-63, 1952.)

Dorsal Region and Bones and Joints

Surface Anatomy. The extensor tendons and their lateral expansions are visible and palpable on the dorsum of the hand. The metacarpal bones are subcutaneous and can be felt over their entire length. The muscle prominence on the dorsum of the hand which is seen when the thumb and forefinger are approximated is formed by the contraction of the first dorsal interosseous muscle. The radial artery passes between the two heads of this muscle and enters the palm. When the thumb is extended, the "anatomical snuffbox" becomes evident. When the fingers are flexed, the prominence of the knuckles represents the distal ends (heads) of the metacarpal bones. The interosseous spaces, although normally leveled out by the dorsal interosseous muscles, are conspicuous when these muscles are atrophied.

Superficial Structures. The dorsal, in contrast to the palmar, surface of the hand is covered with skin of fine texture, studded with short hairs and provided with sebaceous glands. The presence of hairs, sebaceous glands and columns of fat under the dermis predisposes to furuncle and carbuncle formation. The *dorsal subcutaneous space* is an extensive area of loose tissue without definite boundaries, which allows pus to spread over the entire dorsum of the hand.

Dorsal Subaponeurotic Space. On the dorsum of the hand the extensor tendons of the fingers are united by oblique bands, forming an aponeurotic sheet which is a continuation of the fascial sheath over the carpus. This is attached on each side to the borders of the second and fifth metacarpals. The dorsal aponeurotic space lies between this sheath, the dorsal surfaces of the middle four metacarpals, and the interosseous muscles. It contains loose

connective tissue. An infection in the space generally is secondary to wounds on the dorsum of the hand. When pus collects, it is limited by fibrous partitions distally at the metacarpophalangeal joints and proximally by similar partitions at the bases of the metacarpals.

Dorsal Tendons and Muscles. The radial and ulnar extensor muscles of the carpus insert, in this region, into the second, third and fifth metacarpal bones, and the extensor muscles of the thumb and fingers traverse this region to insert into the phalanges (Fig. 861). The characteristic sound of "creaking of new leather" in tenosynovitis of the dorsum of the wrist and hand results from inflammation of the visceral and parietal layers of the tendon sheaths. The radial extensor tendons are most frequently affected.

The *interosseous muscles* are intrinsic in this region. The three volar interossei arise from the metacarpal bones and adduct the little, ring and index fingers toward the middle finger. The four dorsal interossei abduct the ring and index fingers from the middle finger. In addition to these actions, they assist the lumbrical muscles in flexing the fingers at the metacarpophalangeal joints, and, by reason of their insertion into the bases of the proximal phalanges and into the dorsal extensor expansions, aid in extending the fingers at the interphalangeal joints. The interossei are innervated by the deep branch of the ulnar nerve (C 8; T 1).

Metacarpal Bones. The metacarpal bones, one for each digit, articulate through their bases with the distal row of the carpal bones at the carpometacarpal joints (p. 883). Their heads and the proximal phalanges constitute

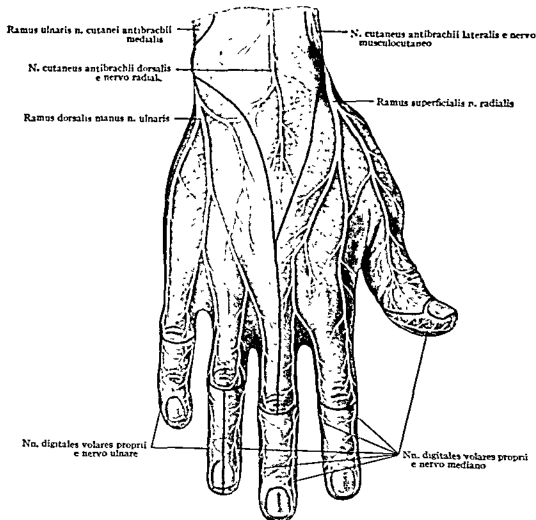


Fig. 860. SURFACE ANATOMY AND AREAS OF CUTANEOUS NERVE DISTRIBUTION OF THE POSTERIOR REGION OF THE WRIST AND HAND.

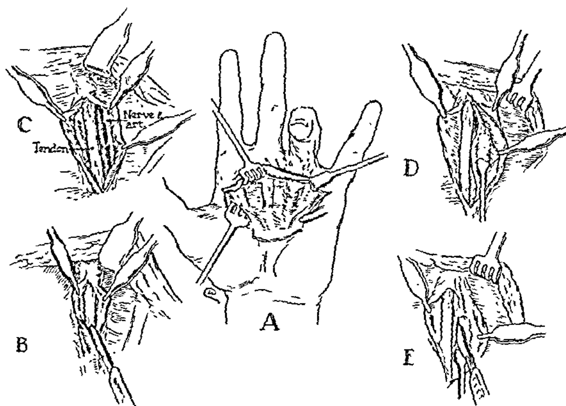


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Dorsal Region and Bones and Joints

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SUPERFICIAL STRUCTURES. The dorsal, in contrast to the palmar, surface of the hand is covered with skin of fine texture, studded with short hairs and provided with sebaceous glands. The presence of hairs, sebaceous glands and columns of fat under the dermis predisposes to furuncle and carbuncle formation. The *dorsal subcutaneous space* is an extensive area of loose tissue without definite boundaries, which allows pus to spread over the entire dorsum of the hand.

DORSAL SUBAPONEUROTIC SPACE. On the dorsum of the hand the extensor tendons of the fingers are united by oblique bands, forming an aponeurotic sheet which is a continuation of the fascial sheath over the carpus. This is attached on each side to the borders of the second and fifth metacarpals. The dorsal aponeurotic space lies between this sheath, the dorsal surfaces of the middle four metacarpals, and the interosseous muscles. It contains loose

are hard to obtain, and the proximal fragment is difficult to immobilize in proper position because of its small size. The fracture often is mistaken for a sprain at the metacarpophalangeal joint.

Reduction and skeletal (wire) maintenance of position are effected by the use of traction incorporated into a plaster wristlet.

In *fracture of the metacarpal shaft* the bone usually is bent into a dorsal angulation, accounted for by the greater strength of the flexor muscles of the hand. The break is oblique, and the bone may be shortened noticeably so that the knuckle recedes from the knuckle line (Fig. 863). Failure to correct the fracture leaves a deformity, and may interfere with the action of the interosseous and lumbrical muscles in extending the terminal phalanx. Displaced fractures require continuous extension by elastic traction. For fractures without displacement or with palmar angulation, the hand may be bandaged about a rounded object grasped in the palm. Open fractures may lead to infection of the palmar fascial spaces (p. 902).

The fracture of the neck of the fifth metacarpal deserves special mention because of its frequency. Reduction can be accomplished by 90 degrees flexion of the fifth metacarpal phalangeal joint and dorsal pressure of the proximal phalanx against the head of the metacarpal to reduce the volar angulation of the head. This position also maintains length of the collateral ligaments to prevent contractures. Immobilization for three weeks is sufficient. The use of a straight extension splint is to be condemned.

Developmentally, the hand begins as a

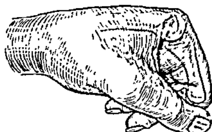


Fig. 862. SHOWING HOW THE PROMINENCES OF THE KNUCKLES, WITH THE FINGERS FLEXED, ARE FORMED BY THE HEADS OF THE METACARPAL BONES.

Attention is directed to the ease with which a blow on the clenched knuckles opens the metacarpophalangeal joint. Without immediate recognition and adequate drainage, this lesion often causes loss of the finger.

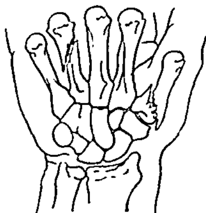


Fig. 863. FRACTURE OF THE THIRD METACARPAL BONE WITH MODERATE SHORTENING AND FRACTURE OF THE BASE OF THE THUMB METACARPAL.

flapper-like broadening of the end of the limb. The fingers become separated by four vertical grooves. These grooves deepen until the flapper becomes separated into five parts, which form the thumb and fingers. The thumb is the first to separate; therefore it is never found webbed. Failure of separation (*webbed fingers* or *syndactylism*) may occur between two or more adjacent processes. As the fingers separate at their distal ends first, the failure may be partial or complete. If partial, two adjacent digits may be united at their bases; if complete, the adjacent digits are united their entire length.

Fingers

The thumb and the four fingers are of the same anatomic construction, except that the thumb has two phalanges and the fingers have three. The short, thick metacarpal of the thumb makes for its strength and mobility. The shafts and distal extremities of the phalanges ossify from primary centers. The proximal ends are formed from separate epiphyses which ossify at three years of age and unite with the diaphyses at twenty years of age.

SURFACE ANATOMY. The transverse flexor creases mark off slightly elevated volar prominences, but do not designate the exact position of the joint lines. The distal transverse crease is somewhat proximal to the distal interphalangeal joint; the middle crease is opposite the interphalangeal joint line; and the proximal crease is a considerable distance distal to the metacarpophalangeal joint. The interphalangeal skin creases are bound down closely to the underlying flexor tendon sheaths. A slight

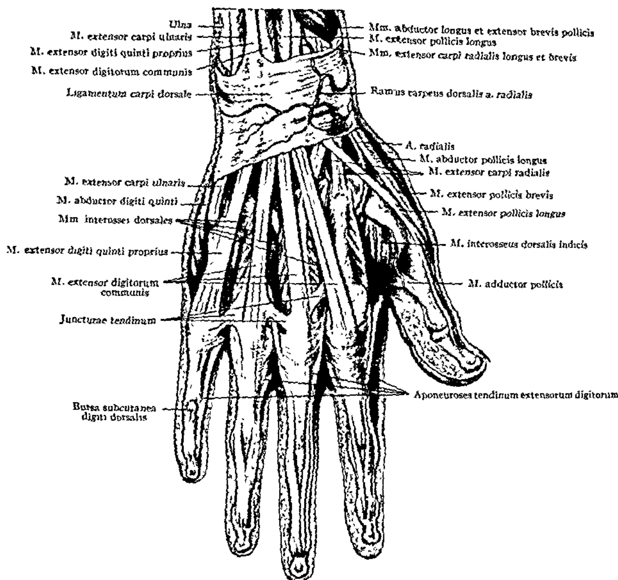


Fig. 861. STRUCTURES ON THE DORSUM OF THE LOWER FOREARM, WRIST AND HAND.

the metacarpophalangeal joints. The shafts are small as compared with the extremities and, therefore, frequently are fractured.

All the flexor and extensor muscles of the wrist overlie the carpus and have their ultimate attachment to the metacarpal bones. The tendon of the flexor carpi radialis is inserted on the palmar surface of the index metacarpal, that of the flexor carpi ulnaris is inserted into the base of the fifth metacarpal, and the extensor carpi radialis longus into the dorsal surface of the base of the index metacarpal. The extensor carpi radialis brevis attaches to the middle metacarpal.

The metacarpal of the thumb ossifies from a primary center in the distal extremity (head), but each of the other metacarpals ossifies from a primary center for the base and shaft and has a separate epiphysis for the head, which ossifies about three years of age and unites with the diaphysis at twenty years of age.

FRACTURES OF THE METACARPALS. The metacarpals are fractured, as a rule, from a blow upon the knuckles when the fist is clenched (Fig. 862). *Fracture of the base of the first metacarpal* (Bennett's fracture) is a disabling injury which results from a blow upon the interphalangeal knuckle of the thumb, or from a blow received on the end of the extended thumb. The large distal fragment is drawn proximally and backward into a decided prominence by the combined action of the flexor and extensor muscles of the thumb. The small proximal fragment, which usually lies a little to the ulnar side of the shaft, is displaced only slightly. Crepitus and abnormal mobility

laceration in a skin crease may easily involve the digital synovia and result in synovitis.

Superficial Structures. The skin of the flexor surface is thick, relatively immobile, and entirely devoid of hair follicles and sebaceous glands. That over the dorsum is thin and mobile, has little subcutaneous fat, and permits free movement over the underlying deep fascia. The *subcutaneous tissue* over the flexor surface is a meshwork of fibrous septa enclosing small columns of fat. These septa bring the thick skin into intimate relationship with the fibrous layers of the tendon sheaths and, in the terminal phalanges, with the periosteum. Within the subcutaneous tissue run the digital vessels and nerves (Figs. 846, 849).

Sheaths of the Flexor Tendons. Deep to the skin and subcutaneous tissue is a resistant fibrous layer whose reflections and attachments to the phalanges form an osteofibrous sheath for the two flexor tendons to each finger. The sheath is strong and resistant over the shafts of the phalanges, but is thin at the level of the interphalangeal joints to allow free flexion. Through these thin areas the digital synovia herniates into the subcutaneous tissue, where it is exposed to infection. The *fibrous sheaths* of the thumb and little finger are similar in structure to those of the index, middle and ring fingers, and are continuous in the palm with the palmar sheath for the thumb flexor (radial bursa) and with the common palmar sheath (ulnar bursa). *Synovial sheaths* which invest the flexor tendons within the osteofibrous canals extend distally to the insertions of the profundus tendons and into the palm a thumbbreadth proximal to the metacarpophalangeal joints (Figs. 864, 865).

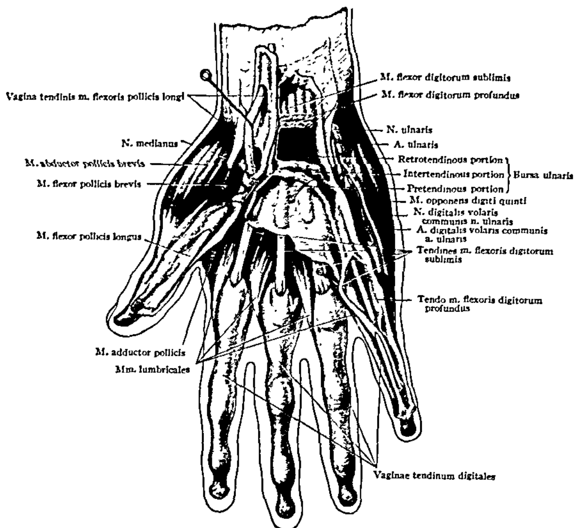


Fig. 865. DIGITAL AND PALMAR SYNOVIA OF THE ANTERIOR REGION OF THE HAND AND FINGERS.

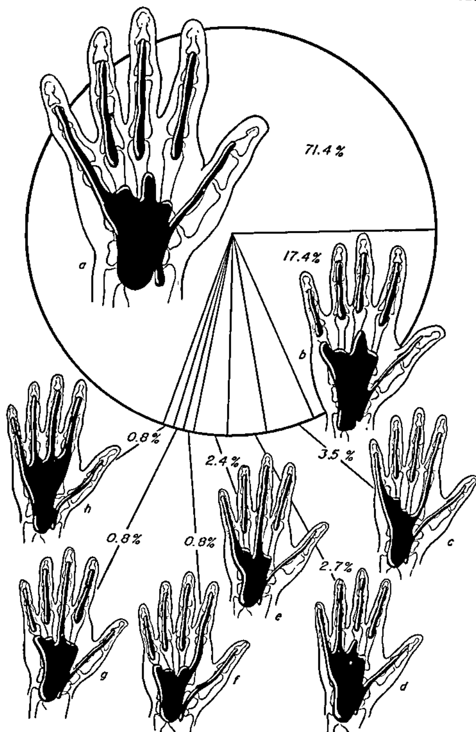


Fig. 864. THE GENERALLY ACCEPTED ANATOMIC PATTERN OF COMMUNICATION IN THE HAND APPEARED IN ONLY ABOUT 71.4 PER CENT OF CASES (*a*).

No communication was found between the flexor tendon sheaths and the ulnar bursa in 17.4 per cent (*b*).

Definite communications to the tendon sheaths of the little and index fingers, but not to the other 2 fingers, showed in 3.5 per cent (*c*).

Communications to the little and ring finger tendon sheaths, but not to the middle and index fingers, were noted in 2.7 per cent (*d*).

The little and middle fingers, but not the ring and index fingers, communicated with the ulnar bursa in 2.4 per cent (*e*).

A connection between the index finger only and ulnar bursa, between the middle finger only and ulnar bursa, and between all the flexor tendon sheaths and the ulnar bursa was observed in 3 hands each (0.8 per cent) (*f*, *g*, *h*).

These patterns show that 8 separate and distinctly different types of anastomoses occur and corroborate the reports of spread of infection that have been appearing in the literature. Physicians should anticipate not only the possibility of infectious diffusion to the ulnar bursa whenever a tendon sheath is inflamed, but also that bursal involvement may similarly spread to a digit. (Scheldrup in Modern Medicine, March 15, 1952.)

parts. The central part is inserted into the base of the second phalanx; and the two lateral slips, after receiving the insertions of the lumbrical muscles (p. 897) and a part of the insertions of the interosseous muscles (p. 907), insert into the bases of the distal phalanges. The remaining portions of the tendons of the interossei, which move the fingers toward and from one another, are inserted into the bases of the proximal phalanges. This specialized tendon expansion is unique in its action on the digits. The insertion on the base of the proximal phalanx subserves the function of extension of the fingers at the metacarpophalangeal joints, and the extensor action of the two terminal phalanges is reinforced by the pull of the interosseous and lumbrical muscles.

The thumb has two separate extensor muscles, the extensor pollicis longus and brevis. On the index and little fingers the tendon expansions are strengthened by the tendons of the extensor indicis and extensor digiti quinti proprius.

Volar Digital Vessels and Nerves. The *common volar digital arteries*, which arise from the convexity of the superficial volar arch, give off the proper digital branches which supply the contiguous sides of the thumb and fingers, and the distal parts of their dorsal surfaces. The proximal part of the dorsum of the fingers is supplied by *dorsal digital arteries* which are the terminations of the dorsal metacarpal arteries from the dorsal carpal arch (Fig. 849).

The proper digital arteries are superficial to the corresponding *volar proper digital nerves* which supply the adjoining sides of the fingers and the distal parts of the dorsal surfaces. The *dorsal proper digital nerves* supply the proximal parts of the dorsum of the fingers (Fig. 873).

The *superficial lymphatics* are numerous over the flexor surface of the fingers and form a mass of anastomotic channels which follow the superficial veins. The *deep lymphatics* accompany the digital vessels. The main branches of the lymphatic network collect into the trunks about the roots of the fingers; these trunks run dorsally toward the wrist and forearm.

Surgical Considerations

Dislocations and Fractures of the Phalanges. Dislocations of the phalanges at the metacarpophalangeal joints occur with moderate frequency because of their ball-and-socket arrangement. Each joint has volar and collateral ligaments, but the dorsal ligament is replaced by the expansion of the extensor tendon. The volar accessory (glenoid) ligament is a fibrocartilaginous plate attached firmly to the proximal phalanx, but connected weakly with the metacarpal.

The usual *dislocation of the thumb* at the metacarpophalangeal joint occurs in forcible dorsiflexion of the thumb as produced by a fall upon the hyperextended hand. A great strain is thrown upon the front of the joint, so that the glenoid ligament gives way at the metacarpal attachment and allows the phalanx to pass backward, carrying the ligament with it. The phalanx comes to rest on the dorsal aspect of the metacarpal head. The head of the metacarpal projects anteriorly, and great difficulty sometimes is encountered in effecting reduction. If traction is put upon the thumb in the direction of the axis of the metacarpal, the tendency for the volar accessory ligament and the head of the phalanx is to become wedged more and more firmly against the metacarpal. To overcome this difficulty, the dislocated thumb is dorsiflexed still further until it forms a right angle with the dorsal surface of the metacarpal. While held in this position, the base of the phalanx is carried steadily toward the head of the metacarpal. As soon as it is thought to have cleared it, and while traction is maintained, the phalanx is flexed abruptly and carried medially toward the palm. This

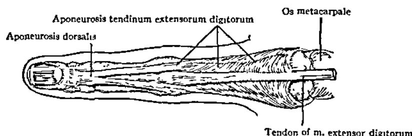


Fig. 867. DORSAL VIEW OF THE EXTENSOR TENDON OF THE FINGER.

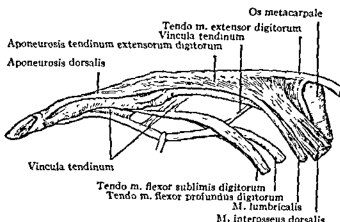


Fig. 866. DISTAL EXTREMITIES OF THE FLEXOR AND EXTENSOR TENDONS OF THE RIGHT MIDDLE FINGER SEEN FROM THE RADIAL SIDE.

The relations of the lumbrical and dorsal interosseous muscles to the aponeurosis of the extensor tendon are emphasized.

Each sheath is divided into visceral and parietal layers, as is the synovia of the flexor pollicis longus tendon. The digital synovia of the thumb is a continuation of the radial bursa, and that for the little finger is continuous with the palmar synovia of the ulnar bursa. The digital synovia of the other fingers is regularly described as being closed proximally (Fig. 857).

According to classical concepts, the synovial sheath of the flexor tendon for the little finger, but not of the three middle digits, has continuity with the ulnar bursa. Communications between the middle fingers and the bursa are regularly considered either nonexistent or anatomic curiosities. However, this theory has been refuted by evidence from a study of the sheaths and bursal configurations in 367 dissected hands (Scheldrup) (Fig. 864).

The generally accepted anatomic pattern of communication in the hand appeared in only about 71.4 per cent of cases (Fig. 864, *a*). No communication was found between the flexor tendon sheaths and the ulnar bursa in 17.4 per cent (Fig. 864, *b*). Definite communications to the tendon sheaths of the little and index fingers, but not to the other two fingers, showed in 3.5 per cent (Fig. 864, *c*). Communications to the little and ring finger tendon sheaths, but not to the middle and index fingers, were noted in 2.7 per cent (Fig. 864, *d*). The little and middle fingers, but not the ring and index fingers, communicated with the ulnar bursa in 2.4 per cent (Fig. 864, *e*). A connection between the index finger only and ulnar bursa, between the middle finger only and ulnar bursa, and between all the flexor tendon sheaths and the ulnar bursa was observed in three hands each, or 0.8 per cent (Fig. 864, *f*, *g*, *h*).

These patterns show that eight separate and distinctly different types of communication may be encountered. Their occurrence corroborates the reports of spread of infection that have been appearing in the literature.

Occasionally there is a condition within the tendon sheath in which the tendon cannot be flexed after it has been extended, or cannot be extended after it has been flexed. The patient usually straightens or closes the fingers with the other hand, the action occurring with a sudden recoil (*trigger finger*). This is due to a localized disparity between the tendon and the sheath. There is either a local enlargement of the tendon or a constriction of its sheath. Any of the fingers may be affected.

INSERTION OF THE FLEXOR TENDONS. In the proximal portion of each digital sheath the sublimis and profundus flexor tendons are superimposed. Opposite the base of the proximal phalanx the sublimis tendon divides into two slips through which the tendon of the profundus passes to its insertion into the volar aspect of the base of the distal phalanx (Fig. 866). The slips of the sublimis tendon continue distally to an insertion into the volar surface of the base and sides of the middle phalanx.

INSERTION OF THE EXTENSOR TENDONS. The common extensor tendons form strong fibrous expansions on the dorsal surfaces of the knuckles and the proximal phalanges; these expansions fuse with the capsules and lateral ligaments of the metacarpophalangeal joints (Fig. 867). On the dorsum of each proximal phalanx the tendon expansion splits into three

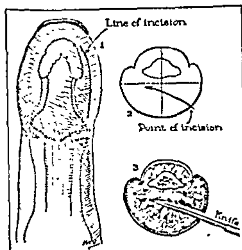


Fig. 870. INCISION FOR DRAINAGE OF INFECTION IN ANTERIOR CLOSED SPACE OF TERMINAL PHALANX (FELON).

(From Koch: J.A.M.A., 92: 1171-3, 1929.)

ment consists in immediate incision into the infected area (Fig. 870). The incision should be made at the side and not in the midline of the tactile part of the finger pad. Usually the diaphysis, rarely the epiphysis, is involved.

A *paronychia* begins as an acute infection in the subepithelial tissue at the side of the nail (Fig. 871). This forms a small abscess, which, if opened, promptly makes a complete recovery. If the infection is neglected, the pus spreads along the side of the nail and back to the base, forming a "runaround." Pus may be expressed from beneath the overlying epithelium (eponychium), and a little later is found under the posterior overhanging edge of the nail. It extends around the nail groove, under the nail, and lifts the soft and delicate root off the nail bed, even when the distal part of the nail still is attached firmly to the matrix (subungual abscess).

The proper *treatment* is to allow the escape of the unexpressed pus. A longitudinal incision is made along the edge of the nail, going back toward the base as far as the sulcus. The detached edge of the nail with as much of the root as has been separated from the matrix is cut off with scissors. After removal of this portion of the nail the elevated flap of overhanging cuticle is lifted up and a pack is inserted beneath it to ensure drainage. If more than half of the base of the nail becomes involved, a second incision is made upon the other side of the nail. The flap made is elevated as before, exposing the entire nail groove. The loosened portion of the nail, often comprising the entire nail root, is removed, leaving the distal part of the nail attached to the matrix. The nail requires about three months to regenerate.

SPREAD OF INFECTION FROM THE DIGITAL SYNOVIA. The three cardinal signs of infection from the digital synovia are excessive tenderness over the course of the sheath and limited to it; a flexion attitude of the involved finger; and severe pain, most marked at the proximal end, on extending the finger. In addition to swelling in the infected finger, there is swelling of the adjacent digits and of the back of the hand.

An infection in the sheath of the tendon of the little finger may be limited to the finger. In a case in which there is continuity between the sheath of the little finger and the common palmar sheath (ulnar bursa), infection may

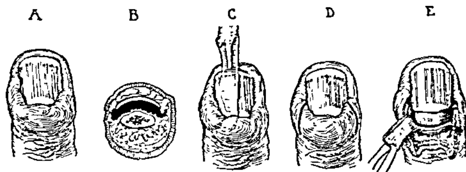


Fig. 871. PARONYCHIA AND ITS TREATMENT.

A, Appearance of paronychia; *B*, cross section of a paronychia, showing the elevation of the root of the nail by the pus sac; *C*, evacuation of an early paronychia by separating the overlying skin from the nail by a thin knife; *D*, incisions for operation of a fully developed paronychia; *E*, removal of the root of the nail after turning back the skin flap. (After Homans and Babcock.)

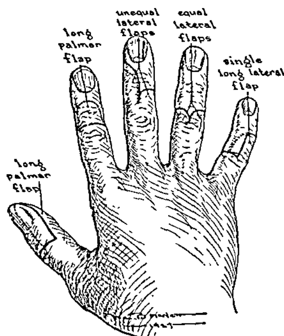


Fig. 868. INCISIONS FOR AMPUTATIONS THROUGH THE FINGERS AND THUMB.

A palmar flap is preferred. (From Babcock: Textbook of Surgery.)

maneuver first disengages the volar accessory ligament and sesamoid bones and subsequently restores the articular surfaces to their normal position.

Dislocations and fractures of the middle and distal phalanges frequently occur when the tip of the finger is struck while the phalanx or phalanges are hyperextended. These dislocations are reduced fairly easily, but dislocation often recurs with deformity if there is an accompanying fracture. It is not uncommon to find the extensor tendon ruptured at its insertion into the base of the terminal phalanx. This causes the terminal phalanx to remain in partial flexion (dropped finger). A fragment of bone usually is torn from the edge of the articular surface. Immobilization of the terminal interphalangeal joint in hyperextension and of the middle interphalangeal joint in 45- to 90-degree flexion for four weeks is necessary. The common use of the straight splint, such as a tongue depressor, should be condemned. It has no place in the treatment of fractures or tendon injuries of the fingers. Some flexion of the interphalangeal joints maintains the tone and length of the collateral ligaments to prevent contractures and stiffness of the interphalangeal joints. Immobilization in complete extension or hyperextension quickly permits periarthritic immobilization of the fingers.

Fractures of the phalanges are frequently open, and the finger may require amputation. Fracture of the proximal phalanx requires a splint extending well into the palm, or traction from a banjo splint. For fractures of the distal and middle phalanges, splints are not necessary. The pull of the interosseous and lumbrical muscles through their attachments into the extensor tendon may tend to draw the distal fragment dorsally.

INFECTIONS OF THE FINGERS. The infection termed a *felon* (whitlow) begins in the skin of the palmar surface of the distal phalanx and rapidly involves the tissues beneath (Fig. 869). The connective tissue framework is such as to produce an anterior closed space comprising the distal part of the phalanx. When pus develops in this closed sac, it has no means of free exit or spread as in other connective tissue spaces, so that its pressure shuts off the blood supply and causes bone necrosis. The base of the phalanx, the epiphysis in the young, gets its blood supply through vessels which do not traverse this dense tissue. Therefore it does not necrose like the rest of the bone. Treat-

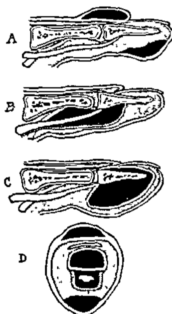


Fig. 869. VARIETIES OF INFECTION ABOUT THE TERMINAL PHALANX.

A, Infection under the epidermis and under the dermis; *B*, infection within the tendon sheath; *C*, infection of the terminal phalanx under the periosteum; *D*, the 4 varieties of infection in cross section. (After Forgue.)

tracture. On the dorsal aspect superficial infections may require drainage (Figs. 872, 869, *A*), but long incisions are not made over joint surfaces. Even with lateral incisions (Fig. 873) the dorsal and volar arteries and nerves are spared in order not to interfere with blood supply or cause areas of numbness and paresthesia.

Incisions for Exposure and Repair of Divided Flexor Tendons. Koch* states that Bunnell, more consistently than anyone else, has stressed the importance of avoiding scar contractures by making incisions along flexion creases and parallel with the lines of cleavage and not across them (Fig. 874). In choosing the exact site and in determining the length of the incision, one should be guided by the position in which the hand was held at the time of injury. If the tendons in the fingers or palm are divided when the fingers are completely extended, the distal segments, which have no contractile power, lie close to the site of injury; the proximal segments are drawn far proximalward by the contraction of the affected muscles. If, on the other hand, the fingers are tightly flexed at the time of injury, there will be relatively little further retraction of the proximal segments, but the distal segments are retracted distalward for a surprisingly great distance when the fingers are extended. It is not uncommon in such a case to find the distal segment of the divided profundus at the level of the proximal interphalangeal joint, even though the division has taken place in the middle of the palm.

*Koch: Division of the Flexor Tendons within the Digital Sheath. Surg., Gynec. & Obst., 78: 9–22, 1944.

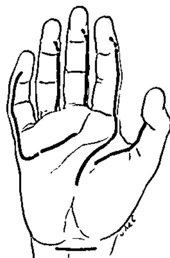


Fig. 874. INCISONS FOR EXPOSURE AND REPAIR OF DIVIDED TENDONS.

If the incisions are made along flexion creases, they heal with a minimum of scar and disabling contracture. (From Koch: Surg., Gynec. & Obst., 78: 9–22, 1944.)

In an operation on the flexor tendon the fibrous tendon sheath is opened by an incision close to its attachment to the bone, never by a median incision. Even if the empty sheath is completely collapsed, it may be possible to open it, save the "roof," and use it eventually as a flap to lay across the repaired tendon and hold it in place. In such circumstances care must be taken not to injure its synovial lining.

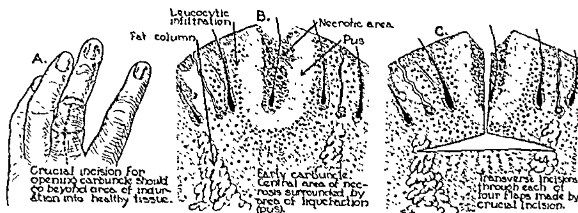


Fig. 872. TREATMENT OF CARBUNCLE OF THE FINGER.

(After Kanavel and Mason.)

extend rapidly into the palm and wrist. The most conspicuous and valuable sign is the extension of tenderness into the areas involved. The infection from the ulnar bursa may extend into the radial bursa, or may rupture through the proximal end of the sheath and extend along the intermuscular spaces of the forearm. At this time, pus may collect subcutaneously above the wrist as a result of lymphangitis.

One of the commonest sites of extension is along the lumbrical muscles into the palmar fascial spaces. Extension into the midpalmar spaces may occur from rupture of the ulnar bursa. The extension of infection from the synovia of the index, middle and ring fingers commonly is along the lumbricals into the palmar fascial spaces. Infection from the middle and ring fingers drains into the middle palmar space (Fig. 851).

The seriousness of the spread of a tenosynovitis of the flexor pollicis longus should be recognized fully. The infection spreads easily into the palmar synovia (radial bursa) and may rupture through the closed proximal end into the intermuscular spaces of the forearm or into the ulnar bursa.

The first incision for drainage of digital tenosynovitis is made at the side of the sheath at the site of known infection. The incision then is carried along the shaft of the proximal or middle phalanx, leaving the part over the joint uncut to prevent prolapse of the tendon, unless there is doubt of free drainage. If there is complete involvement of the synovia, a similar incision is made over the proximal or middle phalanx. No incision, as a rule, is necessary over the distal phalanx. If the palmar synovia is known to be involved by tenosynovitis in the small finger or in the thumb, the ulnar and radial bursae require drainage.

Approach to the Phalanges and Interphalangeal Joints. Incisions are never made on the volar aspects of the fingers, because of the common sensitivity of scars and the possibility of deformity from postoperative con-

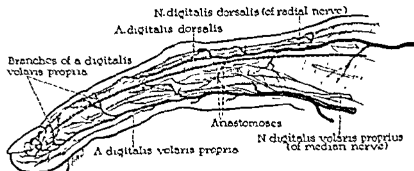


Fig. 873. APPROACH TO THE PHALANGES AND INTERPHALANGEAL JOINTS.

The incisions should be on the lateral aspects of the fingers at the transitional line between the thin dorsal skin and the thicker palmar skin in order to avoid as much as possible the dorsal and volar arteries and nerves. All large branches seen should be carefully spared in order to prevent annoying paresthesias.

except that the brachioradialis and extensor carpi radialis muscles are spared. The wrist can be extended, but the movement is weak. The *superficial branch* of the radial nerve may be injured in lacerations about the dorsal and radial aspects of the wrist, but, unless other nerves are injured, sensory changes often are not apparent because of the communications (overlap) with other nerves.

Separate injury to the trunk of the MUSCULOCUTANEOUS NERVE is rare, but one of its divisions or branches may be cut in wounds of the forearm. Injury to the main trunk of this nerve paralyzes the biceps and coracobrachialis muscles and weakens the brachialis (anticus) muscle. Flexion of the forearm when the hand is supine still can be performed by the brachialis muscle and the superficial flexors of the forearm. With the hand in the prone or midprone position, flexion is aided by the extensor carpi radialis longus and brachioradialis muscles. The motor paralysis is accompanied by disturbance in sensation over the radial half of the forearm. Division of the cutaneous branch of the musculocutaneous nerve causes the same sensory signs as those of injury to the parent trunk. Because of nerve overlap, section of the volar or dorsal branch causes no changes in sensation.

The ULNAR NERVE rarely is injured in the upper arm, but may be damaged in fracture or dislocation at the elbow, or operations about it, because of the superficial position of the nerve and its close proximity to the medial epicondyle of the humerus (p. 855). It is liable to injury from deeply incised wounds at the wrist, where the nerve is superficial. In *severance of the nerve at the wrist* all the intrinsic muscles of the hand are paralyzed save those supplied by the median nerve. Immediately after section of the nerve the injury may be overlooked when no tendons are cut because, on superficial examination, most of the movements of the fingers apparently are performed. It is essential to determine whether or not the patient can separate the fingers; inability to do so indicates paralysis of the dorsal interosseous and abductor digiti quinti muscles. The power of adduction of the thumb is lost, the little finger is more or less paralyzed in all its movements, and there is wasting of the muscles of the hypothenar eminence. The action of the interosseous muscles is lost completely, as is evidenced by inability to flex the fingers at the metacarpophalangeal joints or extend them at the interphalangeal joints. This loss of power is less evident in the index and middle fingers than in the ring and small fingers, since the lumbrical muscles to the index and ring fingers are innervated by the median nerve. The paralyzed muscles atrophy, and the fingers are extended at the metacarpophalangeal joints, since the balance between the flexors and extensors is upset because of the paralysis of the interosseous muscles (Fig. 876). In the small and ring fingers the flexor and extensor equilibrium is upset further by the loss of the lumbrical muscles. As their action on the dorsal extensor expansions is lost, hyperextension of the fingers at the metacarpophalangeal joints and flexion at the interphalangeal joints occur because the common extensor of the fingers can extend the fingers at the metacarpophalangeal joints only. The result is a clawlike hand, *main en griffe*.

If *injury to the ulnar nerve occurs at the elbow*,



Fig. 875. WRIST DROP FROM PARALYSIS OF THE RADIAL NERVE.

CHAPTER 33

Effects of Injury to the Large Nerves of the Upper Limb

Injuries to, and disease affecting, the nerves of the upper limb are manifested by paralysis of muscles or groups of muscles and by loss of sensation. The loss of sensation with involvement of the large nerves is often less than would be expected, in view of their anatomic distribution, since the terminal branches of neighboring nerves overlap widely and may be able to maintain the sensibility of the part. When one of the large nerves alone is involved, the interpretation of the loss of power and sensation usually is easy; when more than one of the nerves is affected, some confusion may arise.

NERVE INJURIES AND THEIR EFFECTS. The nerves most likely to be injured individually are the axillary, radial, musculocutaneous, ulnar and median.

The AXILLARY NERVE, because of its location close to the head of the humerus, often is damaged in dislocation at the shoulder (p. 813), in severe contusions in the deltoid region, by fragments in fracture of the surgical neck of the humerus (p. 819) or by the upward pressure of a crutch. The resulting loss of innervation to the teres minor muscle does not interfere materially with external rotation of the arm. Loss of innervation to the deltoid muscle causes atrophy of the muscle with loss of sensation over its distal part. Abduction of the arm then is performed by the supraspinatus muscle. Deltoid atrophy attributable to nerve involvement must be differentiated from the wasting of disuse in disease of the shoulder joint.

The RADIAL NERVE most frequently is injured individually because of its course and relationships in the arm. It is in intimate contact with the humeral shaft over an area exposed to much trauma. It is likely to be injured in fractures of the distal two thirds of the shaft of the humerus by being caught and crushed by the fragments at the time of accident, or by being compressed by the ensheathing callus (p. 834). It often has been injured in open operations on the shaft of the humerus. Prolonged pressure on the nerve also may harm it: for example, "Saturday night paralysis" is sustained when an intoxicated man falls asleep with his arm hanging over the back of a bench. The pressure of a crutch may injure the nerve in the upper part of the arm where it lies against the shaft of the humerus. Injury usually occurs beyond the origin of the nerve supply of the triceps and anconeus muscles, so that all the remaining muscles supplied directly by the radial nerve and by its deep posterior interosseous branch are paralyzed and the characteristic deformity of *wrist drop* develops (Fig. 875). With this lesion the wrist or fingers cannot be extended voluntarily, but, with the tips of the fingers supported in the effort of extension, the interosseous and lumbrical muscles, which insert into the extensor expansions, extend the fingers at the interphalangeal joints. In the wrist drop occurring in lead poisoning the extensor carpi radialis muscle is affected, but the brachioradialis is not. The elbow is brought against the side in an attempt to rotate the humerus outward to compensate for the loss of the supinator muscles.

The *dorsal interosseous branch* may be injured in dislocation or fracture of the head of the radius (p. 789) or in operations which incise the supinator brevis muscle. In injury to the dorsal interosseous nerve the motor symptoms are as described for wrist drop,

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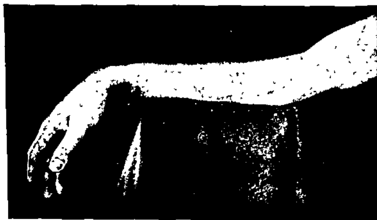


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CHAPTER 33

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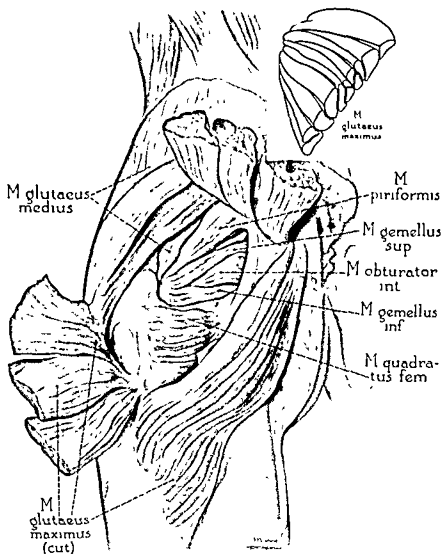
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PART IX

The Lower Extremity



GLUTEAL MUSCULATURE;
MIDDLE SEGMENTS OF THE GLUTAEUS MAXIMUS REFLECTED

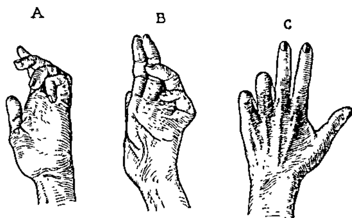


Fig. 876. APPEARANCE OF THE HAND IN PARALYSIS OF THE ULNAR NERVE.
A, Ulnar paralysis of 5 months' duration. *B*, Prolonged ulnar paralysis; the index and middle fingers are hyperextended. *C*, Atrophy of the interosseous muscles. Thumb is abducted because adductor action (ulnar) is lost.

there is, in addition, paralysis of the flexor carpi ulnaris muscle, attended by deviation of the hand to the radial side and limited extension and ulnar flexion. That part of the flexor digitorum profundus muscle which controls the ring and little fingers also is paralyzed. As a result, the terminal phalanges of these fingers are not flexed as acutely as they are in severance of the nerve at the wrist.

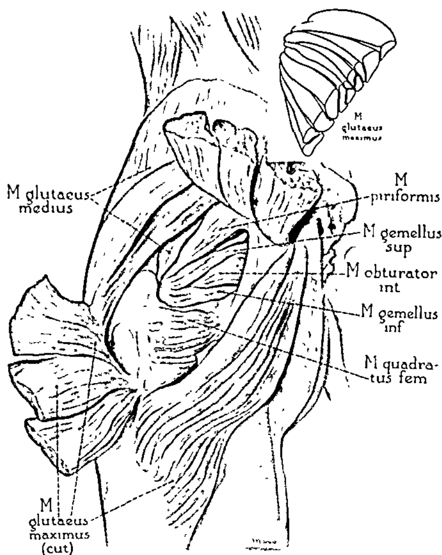
The MEDIAN NERVE rarely is injured alone in the upper arm, but occasionally is damaged by a penetrating wound. The nerve is endangered most in incised wounds of the forearm or wrist, especially in the latter location, where it lies between the tendons of the palmaris longus and the flexor carpi radialis at the upper margin of the transverse carpal ligament (Fig. 849). In injury to the nerve the tendons of the forearm often escape injury.

When the nerve is *severed at the wrist*, the abductor and flexor pollicis brevis, opponens pollicis and the first and second lumbricals are the only muscles affected. Most of the power of abduction of the thumb is lost, although abduction can be performed partially by the abductor pollicis longus muscle, supplied by the radial nerve. There also is difficulty in apposing the thumb to the tips of the other fingers, although the movement of apposition may be imitated by the flexor pollicis longus, supplied by the median nerve in the forearm. In addition to paralysis, there usually is marked wasting of the muscles of the thenar eminence. In attempts to close the hand tightly, the index and middle fingers lag behind the other two, since the balance between the extensors and flexors is disturbed by the lumbrical paralysis. Hyperextension of the index and middle fingers at the metacarpophalangeal joint is not always present, but adduction of the thumb is characteristic when the hand is at rest, because action of the adductor pollicis (ulnar nerve) is unopposed. In a lesion of the nerve at the wrist there is no loss of the power of flexing the wrist and the fingers. As in the injury to the radial nerve, the extent of loss of sensation is subject to great variability.

When the nerve is *severed proximal to the elbow*, the extent of the paralysis is increased greatly, since the injury occurs proximal to the origin of the branches supplying the muscles of the anterior forearm. The power of true pronation of the forearm is lost, but the brachioradialis muscle is capable of producing a midprone position. The loss of power is compensated for to some extent by rotating the humerus inward while carrying the elbow away from the side and allowing the weight of the forearm to complete the action. Attempts at flexing the wrist result in the hand being deviated toward the ulnar side. Flexion is accomplished by the flexor carpi ulnaris muscle and the ulnar half of the flexor digitorum profundus muscle. The thumb is adducted, but its terminal phalanx is extended because of the loss of the flexor pollicis longus muscle. The index and middle fingers are useless, because no flexion is possible at the interphalangeal joints, and the interosseous muscles at best are feeble flexors at the metacarpophalangeal joints when they must initiate the movement. Both the ring and the little fingers are weakened only by the loss of the flexor sublimis tendons.

PART IX

The Lower Extremity



GLUTEAL MUSCULATURE;
MIDDLE SEGMENTS OF THE GLUTAEUS MAXIMUS REFLECTED

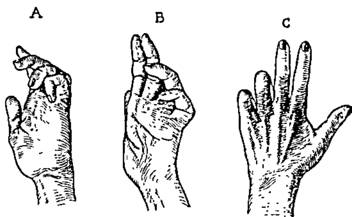


Fig. 876. APPEARANCE OF THE HAND IN PARALYSIS OF THE ULNAR NERVE.
A, Ulnar paralysis of 5 months' duration. *B*, Prolonged ulnar paralysis; the index and middle fingers are hyperextended. *C*, Atrophy of the interosseous muscles. Thumb is abducted because adductor action (ulnar) is lost.

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CHAPTER 34

Hip

The lower extremity is bound to the pelvis by many powerful muscles grouped about the hip joint in the pelvifemoral region. This region is subdivided into the gluteal region and the hip joint.

Gluteal Region

DEFINITION AND BOUNDARIES. The gluteal region is the roughly quadrilateral area of soft parts corresponding to the prominence of the buttocks (Frontispiece, Part IX). It is bounded above by the iliac crest, which separates the region from the posterolateral abdominal wall (Fig. 877); below, by the deep horizontal furrow of the transverse gluteal fold; medially, by the lateral margin of the sacrum and coccyx; and laterally, by the tensor fasciae latae muscle.

LANDMARKS. Abnormal fullness of the buttocks occurs with pathologic conditions such as subgluteal abscess, tumor, or dislocation of the head of the femur. The thick superficial fascia ordinarily obscures the muscle landmarks of the buttocks, but the outline of the *gluteus maximus muscle* sometimes can be seen (Fig. 877). The lower margin of the muscle runs downward and laterally, crosses the middle of the gluteal fold obliquely, and is lost in the general contour of the lateral aspect of the thigh. In active mesial rotation of the thigh a muscle prominence appears just below and lateral to the anterior superior iliac spine. This prominence is formed by the *tensor fasciae latae muscle* superficially, and the *gluteus medius* and *minimus muscles* at a deeper level.

The bony landmarks include the crest of the ilium, the ischial tuberosity, and the greater trochanter of the femur. The prominence of the *iliac crest* varies according to the state of nutrition. It terminates in front at the *anterior superior spine*, which is an important landmark in taking measurements of the lower extremity. The crest ends behind at the *posterior superior spine*, the position of which can be determined best by palpating backward along the crest. The posterior superior spine lies at the level of the second sacral spine, a little less than a handbreadth from the median line, deep to a shallow dimple in the overlying skin. It corresponds closely in position with the center of the posterior part of the sacroiliac joint. The *ischial tuberosity* lies vertically below the posterior superior iliac spine; it is covered by the inferior part of the gluteus maximus muscle in the erect attitude, but not in the sitting posture.

The summit of the *greater trochanter of the femur* lies a palmbreadth below the iliac crest and nearly midway between the anterior superior spine and the tuberosity of the ischium (Fig. 878). Its position is indicated normally by a flattened depression on the lateral aspect of the upper thigh; in thin or wasted persons it is a prominent projection when the thigh is adducted. The fascia lata is stretched tightly across the interval between the summit of the trochanter and the iliac crest, but is relaxed by passive abduction of the thigh, so that the upper edge of the trochanter becomes well defined. In this position the greater trochanter can be grasped between the fingers and thumb, and its anterior and posterior surfaces can be outlined. The fingers can be thrust into the *trochanteric* (*digital*) *fossa*. The depression behind the trochanter overlies the hip joint and the posterior aspect of the neck of the femur. In the depth of the depression between the greater trochanter and the ischial tuberosity, the sciatic nerve can be palpated.

Nélaton's line lies between the anterior superior iliac spine and the ischial tuberosity, and passes through the summit of the greater trochanter when the thigh is flexed partially

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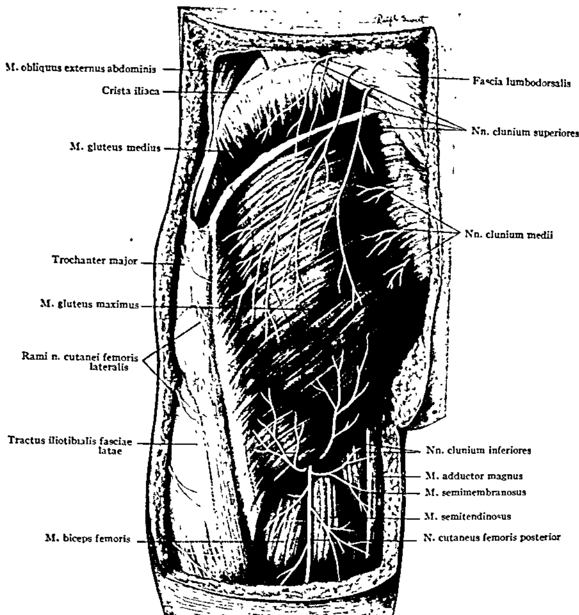


Fig. 877. SUPERFICIAL STRUCTURES OF THE GLUTEAL REGION AND THE POSTERIOR REGION OF THE THIGH.

(Fig. 878). When the summit of the trochanter lies above or below this line, there is a deformity of the neck of the femur. The commonest pathologic conditions diagnosed by this criterion are dislocation of the head of the femur backward and upward on the dorsum of the ilium, and intracapsular and extracapsular fractures of the neck of the femur. The use of Nélaton's line in examination of the hip joint often is impractical because of the difficulty in locating the ischial tuberosity accurately.

Bryant's line extends between the highest point on the greater trochanter and a circumferential line or horizontal plane passing through both anterior superior spines. The distance normally is about 5 cm. Shortening of the line, indicating deformity on the side of the shortening, occurs if the tip of the trochanter is elevated, as in fractures of the neck of the femur. *Bryant's (right-angled) triangle* is constructed with the patient lying on his back (Fig. 879). One side of the triangle is a perpendicular erected from the table to the anterior superior spine. The second side, or base of the triangle (Bryant's line), is a horizontal line drawn from the tip of the greater trochanter to the perpendicular line, and the third side, or hypotenuse, is that part of Nélaton's line which connects the anterior superior spine and the summit of the trochanter (anterior iliotrochanteric line). In fractures of

the neck of the femur the base of the triangle on the affected side is shortened.

The *anterior iliotrochanteric line* connects the anterior superior spine with the tip of the greater trochanter. It forms an iliotrochanteric angle of about 30 degrees with a circumferential line about the pelvis passing through both anterior superior spines. In dislocation or fracture of the neck of the femur this angle is reduced in proportion to the shortening. A rough estimation of this angle by palpation usually permits judgment of the degree of shortening from fracture or dislocation without erecting Bryant's triangle.

The *posterior iliotrochanteric line* (of Farabeuf) connects the posterior superior iliac spine with the tip of the greater trochanter. It corresponds fairly accurately with the interspace (suprapiriformic foramen) (p. 927) between the gluteus medius and piriformis muscles. The junction of the medial and middle thirds of this line is a reliable surface guide to the point at which the superior gluteal artery emerges from the pelvis.

A discussion of the actual and apparent measurements of the lower limbs and the determination of the degree of abduction and adduction at the hip is given on page 934.

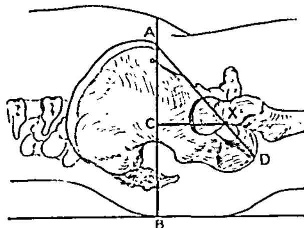


Fig. 879. RELATION OF NÉLATON'S LINE TO BRYANT'S TRIANGLE.

A perpendicular (*ACB*) is dropped from the anterior superior spine to the table. Nélaton's line (*AXD*) extends from the anterior superior spine to the ischial tuberosity. The distance (*XC*) from the summit of the trochanter to the perpendicular (*ACB*) is Bryant's line, or the base of Bryant's triangle (*ACX*). In fracture of the neck of the femur the base (*CX*) of Bryant's triangle is shorter than normal. (Modified from Scudder.)

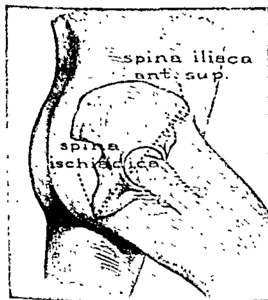


Fig. 878. SURFACE PROJECTION OF THE SKELETAL FRAMEWORK OF THE HIP TO SHOW THE RELATIONS BETWEEN THE ANTERIOR SUPERIOR ILIAC SPINE, THE TUBEROSITY OF THE ISCHIUM AND THE SUMMIT OF THE GREATER TROCHANTER.

Nélaton's line extends between the anterior superior iliac spine and the tuberosity of the ischium (From Babcock: Textbook of Surgery.)

Deep Fascia. The deep fascia of the buttocks is attached strongly to the iliac crest; in its anterosuperior position, where it overlies the gluteus medius muscle, it is a strong aponeurotic sheet. At the upper border of the gluteus maximus muscle the deep fascia splits into two layers which enclose the muscle. The fascia increases in strength at the lateral aspect of the buttock and receives the insertion of most of the fibers of the gluteus maximus and tensor fasciae latae muscles to form the strong iliotibial band.

Gluteal Musculature. The superficial muscle layer includes the gluteus maximus and tensor fasciae latae muscles. The *gluteus maximus muscle* (N. inferior gluteal, L 5; S 1, 2) has a rhomboid outline and is the most massive muscle in the body (Fig. 877). It passes downward and laterally from the posterior part of the iliac crest and the dorsum of the sacrum to an insertion into the deep fascia (iliotibial band) and the upper and outer part of the shaft of the femur from the greater trochanter to the linea aspera. The gluteus maximus covers most of the dorsum of the ilium, the deep layer of the pelvifemoral muscles, the sacrotuberous and sacrospinous (greater and lesser sacrosciatic) ligaments, the suprapiriform and infrapiriform spaces, and

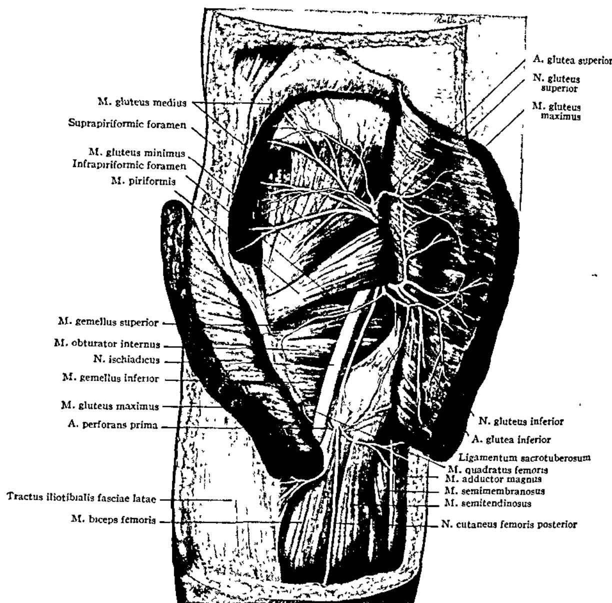


Fig. 880. DEEP STRUCTURES OF THE GLUTEAL REGION.

A large segment of the gluteus medius muscle is removed to expose the gluteus minimus. Attention is called to the piriformis muscle as the key landmark of the deep structures. All the important gluteal vessels and nerves emerge through the suprapiriform and infrapiriform spaces.

the vessels and nerves transmitted by these spaces. The large *ischiogluteal bursa* separates the gluteus maximus from the ischial tuberosity, and another bursa separates it from the greater trochanter. The gluteus maximus is a powerful extensor and external rotator of the thigh.

It is difficult to determine fluctuation through the great bulk of this muscle. The fasciculi composing it are coarse and fibrous and may be separated without damage. Incisions into the buttock are made downward and laterally, parallel to the fasciculi. The areolo-adipose layer under the gluteus maximus sometimes harbors infection spreading from intrapelvic and ischiorectal abscesses.

The *tensor fasciae (femoris) latae muscle* (N. superior gluteal, L 4, 5; S 1) arises from the forepart of the lateral lip of the iliac crest and the subjacent bony surface and is invested by fascia lata (Fig. 880). It lies over the anterior borders of the gluteus medius and minimus muscles, and its fibers pass downward and backward to an insertion into the fascia lata a little below the level of the greater trochanter. This part of the fascia lata, known as the *iliotibial band*, is attached below to the lateral condyle of the head of the tibia.

The deep muscle layer is composed of the gluteus medius, gluteus minimus, piriformis, obturator internus, quadratus femoris and the gemelli muscles. The *gluteus medius* and *minimus muscles* (Fig. 880) are powerful abductors of the thigh. Their forward fibers lie under cover of the tensor fasciae latae and assist in medial rotation.

The *piriformis muscle* (S 1, 2) emerges from the pelvis through the greater sciatic foramen (p. 572). In passing laterally to the tip of the greater trochanter, the muscle tapers to a narrow tendon which lies on the posterosuperior aspect of the capsule of the hip joint.

Inferior to these muscles and on a somewhat deeper plane are the *obturator internus*, the *gemelli*, the *quadratus femoris* muscles and the sacrotuberous ligament. They rotate the thigh laterally.

The *obturator internus* (L 5; S 1, 2) arises from the pelvic surface of the obturator membrane and the os coxae (innominate bone) in the region of the obturator foramen; leaving the pelvis through the lesser ischiadic (sciatic) foramen, it inserts, with the gemelli, into the trochanteric fossa of the femur. The *gemellus superior* (L 5; S 1, 2) takes origin from the spine of the ischium; the *gemellus inferior* (L 4, 5; S 1) arises from the tuberosity of the ischium. The fibers enclose the tendon of the obturator internus and, as elements of a tricipital muscle, have a common insertion (Fig. 880).

The quadratus femoris (L 4, 5; S 1) takes origin on the ischial tuberosity, and runs lateralward to the intertrochanteric crest of the femur.

Vessels and Nerves. Most of the vessels and nerves of the gluteal region traverse the greater sciatic foramen on their way to and from the pelvic cavity. The piriformis muscle passes through this aperture and divides the vessels and nerves into two groups, one above and the other below the tendon. In the supra-piriform space are the superior gluteal vessels and nerves. The *superior gluteal artery*, a branch of the hypogastric artery, enters the gluteal region between the adjoining borders of the gluteus medius and piriformis muscles (Fig. 880). The *superior gluteal nerve* (L 4, 5; S 1) accompanies the superior gluteal artery. These structures can be reached through an incision along the posterior iliotrochanteric line.

Through the infrapiriform space a group of important vessels and nerves emerges from the pelvis. These are the inferior gluteal artery with its companion veins, and the sciatic and posterior cutaneous (small sciatic) nerves (Fig. 880).

The *inferior gluteal* (*sciatic*) *artery* appears at the lower border of the piriformis muscle and runs with the sciatic nerve to the interval between the greater trochanter and the tuberosity of the ischium.

The *crucial anastomosis* is an important connection between the external iliac and hypogastric arterial trunks for the re-establishment of the circulation of the lower limb when the external iliac artery is ligated, or when the femoral artery is divided proximal to the origin of the profunda branch (p. 959). The anastomosis consists of branches of the superior and inferior gluteal arteries from the hypogastric artery, branches of the medial and lateral circumflex arteries, and the first perforating artery, all of which are derived from the profunda femoris artery.

The *sciatic nerve* (L 4, 5; S 1, 2, 3), the largest nerve in the body, is broad and flat. In its downward course to the back of the thigh (Fig. 880) it lies nearly midway between the tuberosity of the ischium and the greater trochanter. The nerve may be approached through a vertical incision along the thigh from the center of the line joining the ischial tuberosity to the greater trochanter. Division of the superficial tissues and the deep fascia exposes the lower margin of the gluteus maximus muscle and the biceps femoris muscle. The nerve lies in the angle between the two muscles and can be hooked up from under cover of the biceps muscle.

In leaving the pelvis through the greater sciatic (ischiadic) foramen, the sciatic nerve usually passes under the piriformis muscle, that is, through the infrapiriform recess. This relationship obtained in 89 per cent of 2000 extremities (Fig. 881, *a*). The muscle, however, may split into two heads; the nerve, too, may have entirely separate tibial and common peroneal components. Of the five schemes of relationship which might occur when either the nerve or the muscle is present in the separate form, three were actually encountered: the divisions of the nerve passed between and below the heads of the muscle in 10 per cent of cases (Fig. 881, *b*); they passed above and below the undivided muscle in 0.65 per cent (Fig. 881, *c*); and the undivided nerve passed between the heads of the divided muscle in

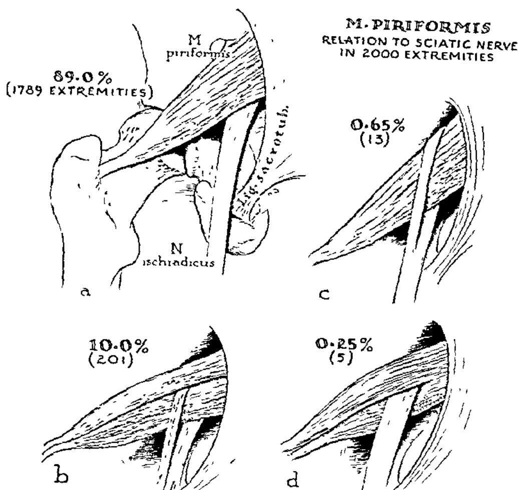


Fig. 881. FOUR TYPES OF ARRANGEMENT OF THE SCIATIC NERVE, OR OF ITS SUBDIVISIONS, IN RELATION TO THE PIRIFORMIS MUSCLE, IN THE ORDER OF DECREASING FREQUENCY OF OCCURRENCE.

The percentage incidence is indicated. *a*, The undivided nerve passes out of the greater ischiadic foramen, below the piriformis muscles. *b*, The divisions of the nerve pass between and below the heads of the muscle. *c*, Divisions above and below the undivided muscle. *d*, Nerve undivided between the heads of the muscle. (Adapted with augmented data from Beaton and Anson: J. Bone & Joint Surg., 20: 686–8, 1938.)

0.25 per cent (Fig. 881, *d*). It is likely that, in some cases of coccygodynia, the pain is due to the clamping effect of the muscle upon the sciatic nerve, or part of the nerve, which courses from the pelvis into the buttock through the substance of a divided piriformis muscle.

The *posterior cutaneous (small sciatic) nerve* (S 1, 2, 3) of the thigh runs downward under cover of the gluteus maximus muscle on the surface of the sciatic nerve. At the lower part of the gluteus maximus it crosses the biceps muscle superficially, and runs down the thigh in the midline of the limb just beneath the deep fascia.

The inferior gluteal vessels may be exposed by an incision parallel to the fibers of the gluteus maximus muscle, cutting the line connecting the posterior superior spine and the ischium at the junction of its middle and lower thirds.

Surgical Considerations

Bursae under the Gluteus Maximus Muscle. Large bursae separate the gluteus maximus muscle from the tuberosity of the ischium and from the greater trochanter. The *bursa over the tuberosity of the ischium* (*ischiogluteal bursa*) may become irritated and inflamed in habitual sitting on a hard surface, as tailors, draymen and horsemen do; hence the term "tailor's" or "weaver's bottom." Bursal enlargement is caused by excessive thickening of the bursal wall by layers of fibrous tissue. The bursal cavity is not increased in size, but, if the swelling becomes

large enough to cause inconvenience, the entire bursa may be excised. This bursitis requires differentiation from a gumma or cold abscess, both of which may occur here.

The *trochanteric bursa* frequently is chronically inflamed from tuberculosis. In *ischiogluteal bursitis*, flexion of the thigh puts pressure on the tender bursa and elicits pain referred to the buttock. Flexion of the trunk produces the same pain as thigh flexion, and for the same reason. The inflammation may terminate in suppuration, evacuation of which may produce a chronic sinus. Pus from suppuration in a trochanteric or an ischial bursa may point about the inferior margin of the gluteus maximus muscle and descend under the deep fascia of the thigh. A bursa sometimes is present between the tendon of the gluteus maximus and the vastus lateralis muscles.

WOUNDS IN THE GLUTEAL REGION. Stab or gunshot wounds in the buttocks may involve intrapelvic structures. The path of the wound usually is directed from behind the greater trochanter through the greater sciatic foramen into the pelvis, and the parts most liable to injury are the gluteal and pudendal vessels, the ureter and the bladder. If the arteries are divided, there follows an extravasation of blood under the gluteus maximus muscle with the development of a traumatic aneurysm. An injury to the bladder or ureter may result in a urinary fistula on the buttock. An injury to the rectum is likely to produce a fecal fistula. The sciatic nerve may be severed.

SUBGLUTEAL ABSCESSES. Abscesses sometimes lie under the gluteus maximus muscle. They reach this location from the pelvis by way of the greater sciatic foramen or the eroded capsule about a suppurating hip joint. Occasionally they occur from hypodermic injections or penetrating wounds. The abscess may cause a prominence of the gluteus maximus muscle, making the buttock fuller than normal and the overlying skin smooth and glossy. These deep abscesses, unless evacuated early, gravitate downward, point distal to the inferior border of the gluteus maximus muscle, and obliterate the transverse gluteal fold. Pus may follow the sciatic nerve down the thigh to the back of the knee.

GLUTEAL HERNIAS. Rarely, a hernia leaves the pelvis through the sciatic foramen and protrudes into the gluteal region. The usual site of appearance of a gluteal hernia is superior to the piriformis muscle, and the sac lies under the gluteus maximus muscle. Branches of the superior gluteal artery may spread over the exterior of the sac. If the hernia continues to enlarge, it emerges at the inferior margin of the gluteus maximus muscle. The neck of the sac usually lies in the ovarian fossa (p. 652) of the pelvis in the angle between the hypogastric and obturator arteries. Herniotomy requires an incision in the posterior iliotrochanteric line (p. 925), in the direction of the fibers of the gluteus maximus muscle, sometimes combined with an intrapelvic exposure of the sac.

Hip Joint

In the hip joint the rounded head of the femur articulates with the cup-shaped acetabulum on the outer aspect of the hip bone (Fig. 882). The hip joint is remarkable for its stability in weight-bearing, for its ability to withstand shock and for its variety and range of motion. It helps maintain the body in erect posture without excessive sustained muscle action. Since the essential characteristic of the hip joint is stability, the chief aim in the treatment of its pathologic conditions is the retention of this stability. If mobility also can be obtained, the result is better, but mobility without stability is useless. The hip joint differs from the shoulder joint in that the bones are heavier and have more prominent processes, and the muscles surrounding it are larger and more powerful. It often is the seat of fracture, dislocation and deformity, and frequently is affected by disease.

ACETABULUM. The acetabulum is a deep hemispheric socket, 3.5 cm. in diameter, located on a high ridge of compact bone connecting the anterior superior iliac spine with the ischial tuberosity. It divides the external surface of the hip bone into an anterior portion, sloping anteriorly and medially, and a posterior portion, sloping backward. These slopes influence the direction taken by the head of the femur when it is dislocated.

The ilium, ischium and pubis share in the formation of the acetabulum and at birth are set apart from each other by a triradiate or Y-shaped bar of cartilage (p. 573). This cartilage begins to ossify at the twelfth year, and the bony segments fuse by the sixteenth

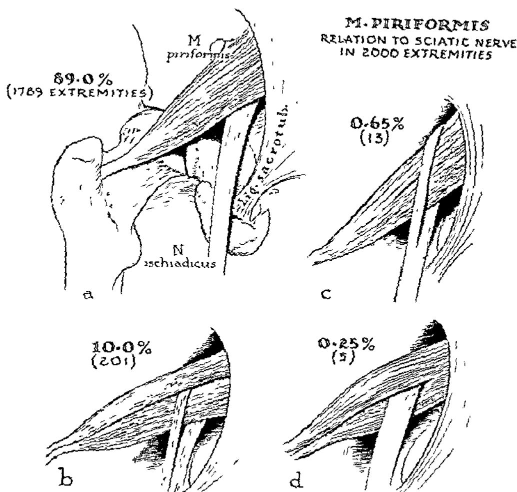


Fig. 881. FOUR TYPES OF ARRANGEMENT OF THE SCIATIC NERVE, OR OF ITS SUBDIVISIONS, IN RELATION TO THE PIRIFORMIS MUSCLE, IN THE ORDER OF DECREASING FREQUENCY OF OCCURRENCE.

The percentage incidence is indicated. *a*, The undivided nerve passes out of the greater ischiadic foramen, below the piriformis muscles. *b*, The divisions of the nerve pass between and below the heads of the muscle. *c*, Divisions above and below the undivided muscle. *d*, Nerve undivided between the heads of the muscle. (Adapted with augmented data from Beaton and Anson: J. Bone & Joint Surg., 20: 686–8, 1938.)

0.25 per cent (Fig. 881, *d*). It is likely that, in some cases of coccygodynia, the pain is due to the clamping effect of the muscle upon the sciatic nerve, or part of the nerve, which courses from the pelvis into the buttock through the substance of a divided piriformis muscle.

The *posterior cutaneous* (*small sciatic*) *nerve* (S 1, 2, 3) of the thigh runs downward under cover of the gluteus maximus muscle on the surface of the sciatic nerve. At the lower part of the gluteus maximus it crosses the biceps muscle superficially, and runs down the thigh in the midline of the limb just beneath the deep fascia.

The inferior gluteal vessels may be exposed by an incision parallel to the fibers of the gluteus maximus muscle, cutting the line connecting the posterior superior spine and the ischium at the junction of its middle and lower thirds.

Surgical Considerations

Bursae under the Gluteus Maximus Muscle. Large bursae separate the gluteus maximus muscle from the tuberosity of the ischium and from the greater trochanter. The *bursa over the tuberosity of the ischium* (*ischiogluteal bursa*) may become irritated and inflamed in habitual sitting on a hard surface, as tailors, draymen and horsemen do; hence the term "tailor's" or "weaver's bottom." Bursal enlargement is caused by excessive thickening of the bursal wall by layers of fibrous tissue. The bursal cavity is not increased in size, but, if the swelling becomes

large enough to cause inconvenience, the entire bursa may be excised. This bursitis requires differentiation from a gumma or cold abscess, both of which may occur here.

The *trochanteric bursa* frequently is chronically inflamed from tuberculosis. In *ischiogluteal bursitis*, flexion of the thigh puts pressure on the tender bursa and elicits pain referred to the buttock. Flexion of the trunk produces the same pain as thigh flexion, and for the same reason. The inflammation may terminate in suppuration, evacuation of which may produce a chronic sinus. Pus from suppuration in a trochanteric or an ischial bursa may point about the inferior margin of the gluteus maximus muscle and descend under the deep fascia of the thigh. A bursa sometimes is present between the tendon of the gluteus maximus and the vastus lateralis muscles.

WOUNDS IN THE GLUTEAL REGION. Stab or gunshot wounds in the buttocks may involve intrapelvic structures. The path of the wound usually is directed from behind the greater trochanter through the greater sciatic foramen into the pelvis, and the parts most liable to injury are the gluteal and pudendal vessels, the ureter and the bladder. If the arteries are divided, there follows an extravasation of blood under the gluteus maximus muscle with the development of a traumatic aneurysm. An injury to the bladder or ureter may result in a urinary fistula on the buttock. An injury to the rectum is likely to produce a fecal fistula. The sciatic nerve may be severed.

SUBGLUTEAL ABSCESSES. Abscesses sometimes lie under the gluteus maximus muscle. They reach this location from the pelvis by way of the greater sciatic foramen or the eroded capsule about a suppurating hip joint. Occasionally they occur from hypodermic injections or penetrating wounds. The abscess may cause a prominence of the gluteus maximus muscle, making the buttock fuller than normal and the overlying skin smooth and glossy. These deep abscesses, unless evacuated early, gravitate downward, point distal to the inferior border of the gluteus maximus muscle, and obliterate the transverse gluteal fold. Pus may follow the sciatic nerve down the thigh to the back of the knee.

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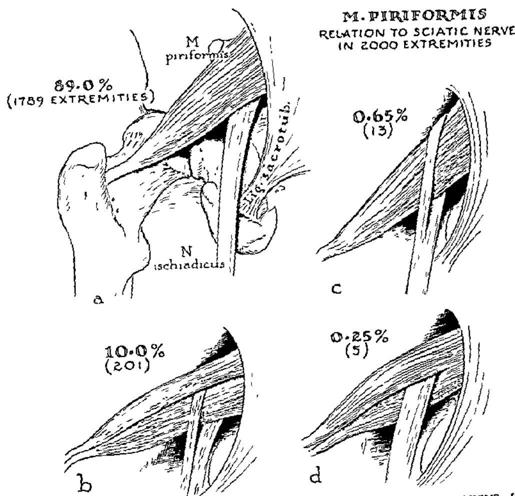


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PROXIMAL EXTREMITY OF THE FEMUR. The *head of the femur* forms more than half a sphere. Its globoid surface is covered by cartilage as far as its junction with the neck. A small pitlike depression (fovea capitis), located a little behind the summit of the head, lodges the femoral attachment of the ligamentum teres, through which the head receives a small arterial supply.

In order to increase the power and mobility of the lower limb and to distribute the body weight over a wider base, the *neck of the femur*, which is an upward extension of the shaft, is inclined to the shaft at an angle which varies from 160 degrees in the child to 125 degrees in the adult (*angle of inclination, vertical neck-shaft angle*) (Fig. 883). The head and neck of the femur lie on a plane a little oblique to that of the line joining the two condyles. The extent to which the axis of the neck is thrust obliquely ahead of the bicondylar plane determines the *angle of declination* (*torsion, forward neck-shaft angle*) (Fig. 884).

A knowledge of the angles of inclination and declination is a valuable aid in the diagnosis and treatment of fractures of the upper end of the femur. Stereoscopic x-ray examination determines accurately the relation of the fragments and any change in these angles. Abnormal alterations in the angle of inclination may interfere seriously with the mobility of the hip joint. In congenital dislocation of the hip or in early extensive infantile paralysis the angle of inclination may be increased, because the neck of the femur does not maintain its share of the body weight. Increase in the angle

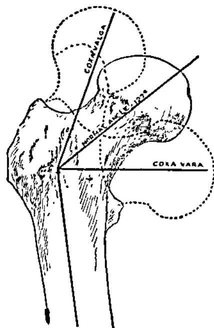


Fig. 883. NORMAL AND ABNORMAL ANGLES OF INCLINATION OF THE AXES OF THE NECK AND THE SHAFT OF THE FEMUR (VERTICAL NECK-SHAFT ANGLES).

(Davis, after Nifong.)

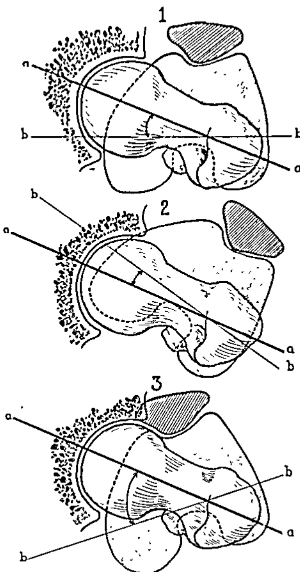


Fig. 884. VARIATIONS IN THE ANGLE OF TORSION (DECLINATION) BETWEEN THE AXIS OF THE NECK OF THE FEMUR AND THE TRANSVERSE BICONDYLAR AXIS.

In 1 the axis of the femoral neck normally projects obliquely anterior to the bicondylar axis. In 2 the axis of the femoral neck projects posterior to the bicondylar axis. In 3 the axis of the femoral neck projects far anterior to the bicondylar axis.

Fig. 882. FRONTAL SECTION THROUGH THE HIP JOINT.

or seventeenth year. Over by far the greater part of its extent the acetabulum is delimited by a sharp bony rim of compact bone. The continuity of this rim is interrupted below by a broad deep notch, the *acetabular* (*cotyloid*) *incisura*. The notch extends upward to an irregular rough area in the floor of the acetabulum which lodges and forms an attachment for the *ligamentum teres*, or intra-articular ligament of the hip joint.

The *transverse ligament* bridges over the acetabular notch and completes the circumference of the acetabulum (Fig. 882). The articular cartilage forms a broad strip around the acetabulum, but the floor of the cavity and the acetabular (cotyloid) notch are nonarticular. Both the transverse ligament and the margin of the acetabulum are overlaid by, and give attachment to, a circular band of fibrocartilage, the *glenoid labrum* (*cotyloid ligament*). This structure deepens the socket for the head of the femur and reduces the diameter of the acetabular inlet. It is pulled around the head of the femur like an airtight collar, so that, even after the joint has been opened, it is not easy to pull the head of the femur out of its socket.

The *floor of the acetabulum* is related internally to the flat surface of the bone which affords attachment to the obturator internus muscle (p. 584) and forms the lateral bony wall of the pelvic cavity. The bone of the rough nonarticular part of the acetabulum is thin, and may be eroded by destructive hip joint disease or be fractured by the head of the femur. The latter injury usually is designated as a central dislocation of the head of the femur (p. 947).

The upper part of the acetabulum is strong and forms part of the powerful buttress which extends upward in front of the greater sciatic notch to the sacroiliac joint and, in the erect posture, transmits the weight of the trunk to the head of the femur. Another strong buttress extends downward from the inferior and posterior part of the acetabulum to the ischial tuberosity. It transmits part of the weight of the body in the sitting position.

the *quadratus femoris* muscles; they pass across the posterior surface of the joint and are inserted into the greater trochanter and into the proximal part of the shaft. The chief internal rotators are the anterior portion of the gluteus medius and the tensor fasciae latae muscles. The gluteus medius and minimus muscles, which are attached to the greater trochanter, are abductors. The length of the neck of the femur and the prominent projection of the greater trochanter afford powerful leverage to the muscles attached to this bony prominence.

MOVEMENTS. There are all varieties of movement at the hip joint. *Flexion*, especially, has a free range. When the knee is flexed, the movement is checked only by contact of the thigh with the anterior abdominal wall; when the knee is extended, however, flexion of the hip is much less free, and straight leg-raising (p. 578) cannot be carried beyond a right angle because of the tension of the hamstring muscles. *Extension* is checked by the iliofemoral ligament when the lower limb reaches a few degrees behind a straight line with the trunk. This stout ligament, stretched over the head and the anterior aspect of the neck of the femur, powerfully braces the front of the joint.

The movement of *abduction* is free until it is checked by the pubocapsular ligament and by contact of the upper part of the neck of the femur with the acetabular margin. *External rotation* is checked by the iliofemoral ligament when the thigh is extended. *Adduction* of the thigh is limited because of the limbs coming into contact. The range of adduction is appreciable when the thigh is flexed slightly, but is restricted in this position by the iliofemoral ligament and the upper part of the capsule. *Internal rotation* is limited by the iliofemoral ligament when the thigh is extended, and by the ischiocapsular ligament when the thigh is flexed.

Surgical Considerations

EXAMINATION OF THE HIP JOINT. The gait may aid in making the diagnosis of hip joint disturbance, so that, if possible, the patient should walk stripped. A limp or a limitation of active movement is observed carefully. The patient is then placed on his back on a hard surface, and the bony prominences are outlined and marked. The position of the femoral head is determined. The measurements of both limbs are taken, and the nature and extent of the active and passive motions are studied. Hyperextension is studied with the patient in the prone position, with his pelvis fixed by placing the hand on his sacrum. The distance the thigh may be lifted from the table is meas-

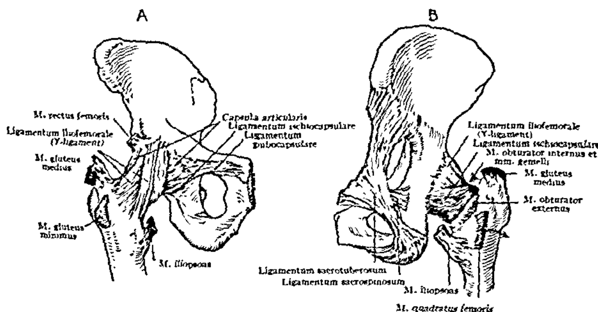


Fig. 885. LIGAMENTS AND TENDONS ABOUT THE HIP.

A, Anterior view; *B*, posterior view.

of inclination is known as *coxa valga*. As a result of constitutional diseases, such as rickets and osteomalacia, or of injuries to the neck of the femur during infancy, the body weight may reduce the inclination of the neck to the shaft to 90 degrees or less. This condition is termed *coxa vara*.

The *greater trochanter* is a quadrilateral mass of bone capping the upper and lateral extremity of the shaft of the femur. Its medial surface fuses with the cancellous tissue of the neck and shaft of the femur. The upper posterior portion of the trochanter is free and overhangs the posterosuperior aspect of the neck of the femur, forming with it the deep pit known as the trochanteric fossa. The lateral surfaces and borders of the greater trochanter afford attachment to muscles from the gluteal, obturator and pelvic regions which help control rotation and abduction in the lower extremity. The tip or most prominent point of the greater trochanter is toward its posterior surface opposite the center of the hip joint. The *lesser trochanter* is on the medial and posterior surface of the shaft, at a more inferior level than the greater trochanter. The anterior and posterior intertrochanteric line and crest run in front of and behind the neck of the femur. They are roughened to accommodate the attachments of the various rotators of the hip and for the attachment of the capsular ligament.

At birth the entire proximal end of the femur is cartilaginous. Development of the head of the femur is from an epiphysis in which a bony nucleus appears in the first year. This epiphysis joins the neck between the eighteenth and twentieth years. The neck is ossified by a proximal extension from the diaphysis. The greater trochanter begins to ossify in the second year, and joins the neck and shaft in the eighteenth or nineteenth year. The lesser trochanter has a separate epiphysis which appears about the twelfth year and joins the shaft in the eighteenth year.

Capsule and Its External Reinforcing Ligaments. The *capsule* of the hip joint has great strength; it is attached proximally to the bony circumference of the acetabulum, to the glenoid labrum (cotyloid ligament) and to the transverse ligament. All the anterior surface and the medial half of the posterior surface of the neck of the femur are intracapsular.

Almost all the blood vessels entering the head of the femur reach it by way of the capsular attachments. A subcapital fracture of the neck of the femur, proximal to the inferior capsular attachment, destroys all the blood supply to the central fragment except that entering through the ligamentum teres. This fragment is dependent on new blood vessels growing in from the femoral neck to supplement this supply. Sclerosis of the proximal fragment often ensues. When some portion of the capsule is attached to the proximal fragment, as occurs in fracture through the base and distal half of the neck, there are better prospects for union.

The capsule is reinforced by certain accessory bands, the iliofemoral, pubocapsular and ischiocapsular ligaments (Fig. 885). The *iliofemoral ligament* (*Y-ligament of Bigelow*), the strongest in the body, thickens the anterior part of the capsule. It passes downward from its origin at the anterior inferior spine and spreads fanlike to an insertion into the anterior intertrochanteric line. The Y-ligament is under tension in all movements at the hip save flexion, and its role is of prime importance in the mechanics of dislocation of the hip.

The posterior capsule is reinforced by the *pubocapsular* and *ischiocapsular* ligaments, which are much weaker than the iliofemoral ligament. The *ischiocapsular* (*ischiofemoral*) *ligament* lies over the posterior aspect of the capsule and helps to prevent too great a degree of medial rotation.

The *ligamentum teres* is intracapsular but extrasynovial. It is a triangularly flattened band attached proximally to a broad base in the acetabular notch and transverse ligament. By its distal narrow extremity it is attached to a small depression on the summit of the head of the femur (fovea). It is completely surrounded by a tube of synovial membrane.

The *synovial membrane* of the hip joint covers the deep surface of the capsule. At the distal attachment of the capsule the synovia is reflected to the femoral neck.

Reinforcing Muscles of the Hip Joint. The strength of the hip joint depends considerably upon the powerful muscles surrounding it. The iliopsoas muscle overlies the capsule anteriorly and inserts into the lesser trochanter. The external rotator muscles are the piriformis, gemelli, obturator and

level. The normal limb is placed in a corresponding position.

APPARENT MEASUREMENTS OF THE LOWER LIMBS. The abnormal positions assumed by the lower extremities in hip joint disease result from muscle action. Usually neither abduction nor adduction of the limb is recognized as such by the patient. The usual complaint is that one limb seems longer or shorter than the other. The explanation of apparent lengthening and shortening lies in the degree of tilting of the pelvis and in the degree of adduction or abduction at the hip. The degree of tilting of the pelvis is determined by drawing a line from the anterior superior iliac spine of one side to the anterior superior iliac spine of the other side. The line normally is at a right angle to the long axis of the body.

Figures 886 to 888 explain the findings. The normal relation of the pelvis to the limbs is shown on the left of each figure. In this position both lower extremities are nearly at a right angle to the pelvis, which is the normal position for standing or walking. If the right leg is fixed by muscle spasm or is ankylosed in an adducted position, the relationships are changed. In order to make the legs parallel for standing or walking, the pelvis is tilted upward on the adducted side. It is apparent that the elevation of the pelvis on the right carries the right limb upward. To all appearances, the adducted right leg is shorter than the abducted left leg when the patient stands or lies straight. That these differences are apparent only is shown by comparing measurements from the umbilicus to the internal malleoli with those from the anterior superior iliac spines to the internal malleoli.

If the *left leg is fixed in abduction* by muscle spasm or ankylosis, the pelvis must be tilted upward on the sound side to make the legs parallel for standing or walking. The left leg then appears longer than the right. The amount of apparent lengthening depends upon the

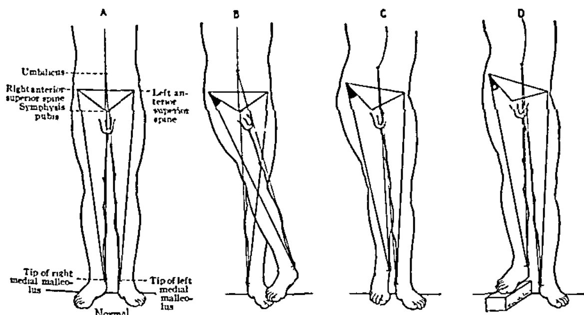


Fig. 887. DIAGRAMS ILLUSTRATING APPARENT SHORTENING IN THE RIGHT LOWER LIMB IN WHICH THE HIP IS FIXED IN ADDUCTION, EITHER BY MUSCLE CONTRACTION OR BY ANKYLOSIS. THERE IS NO BONY SHORTENING OF EITHER LOWER EXTREMITY.

A, Normal person, in whom there is no actual or apparent shortening. *B*, The right thigh is fixed in adduction. The actual or bony measurements of the lower limbs are equal, but the apparent measurements, taken from the umbilicus to the medial malleoli, show that the adducted limb is apparently shortened. Unless the pelvis is tilted upward on the side of the adducted thigh, the right leg cannot be brought parallel with the left in a walking position. *C*, The adducted right extremity is brought parallel with the left extremity by an upward tilting of the pelvis on the adducted side. This maneuver throws the trunk to the left to restore balance. The left thigh is forced into an abduction position. It is obvious that the adducted extremity is apparently shortened and that the heel is elevated and the toes are depressed. The actual measurements are the same. *D*, Support is placed under the adducted extremity to allow locomotion.

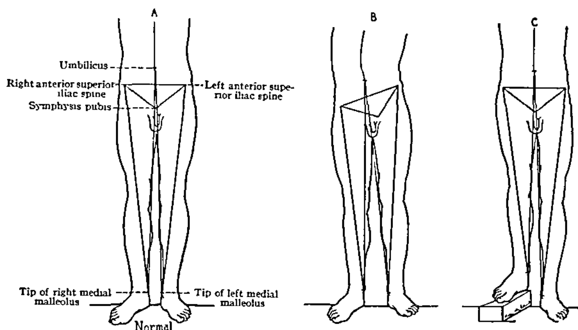


Fig. 886. DIAGRAMS ILLUSTRATING ACTUAL OR BONY SHORTENING OF THE LOWER EXTREMITY.

A, Equal lower extremities, in which measurements from the anterior superior iliac spines to the medial malleoli are identical. *B*, The right lower extremity is actually much shorter. In order to place both feet upon the ground, the pelvis must be tilted down on the short side. The trunk is shifted to the left to maintain balance. *C*, Lift is placed under the short leg. This restores the pelvis to the normal horizontal position and brings the trunk upright.

ured. The roentgenogram is an important adjunct in the diagnosis of injury or disease in the hip.

ACTUAL OR BONY MEASUREMENT OF THE LOWER LIMBS. Comparative measurement of the actual length of the two limbs is essential in the diagnosis and important in the treatment of injury or disease in the hip region. The ability to measure accurately requires knowledge, care and practice. It is not unusual for the limbs to show trifling differences in length; a difference not exceeding 1 cm. is disregarded, because it does not alter the gait. Bony landmarks are preferable to soft parts in accurate measurements. The bony points must be identified carefully, and the measuring tape must be applied accurately. It is essential that the pelvis be not tilted and that the limbs be in corresponding positions. To rule out lateral tilting of the pelvis, it is necessary that a line joining the anterior superior spines be at right angles to the long axis of the body (linea alba).

Measurements are made from the anterior superior spine to the distal margin of the medial condyle of the femur and from that point to the tip of the medial malleolus; or the measurement may be made directly from the anterior superior spine to the medial malleolus across the middle of the patella. The tip of the medial malleolus usually is easy to identify, but the anterior superior spine is not found so readily. The iliac crest is followed forward until its anterior superior spine can be felt distinctly. It is more satisfactory to press the tape firmly upward and backward against the inferior surface of the spine than to rest it upon the skin over the most superficial surface of the spine. The anterior superior spine often is so rounded that it is an uncertain point from which to measure. The deformity in femoral shortening may be ascribed to the shaft or to the surgical neck by comparing the measurements from the tip of the greater trochanter to the distal margin of the lateral femoral condyles, in addition to measuring the distance between the anterior superior spine and the medial malleolus. If the measurements from the trochanter to the condyle are equal, the deformity is in the femoral neck; if they are unequal, the deformity is in the shaft.

To obtain comparable measurements when one hip is ankylosed, the affected femur is moved with the pelvis until the line joining the anterior superior spines is at a right angle to the long axis of the body, and the pelvis is

ulum (p. 572). Involvement of the joint is opposed only by the articular cartilage.

The diagnostic symptoms in the course of hip joint tuberculosis present points of anatomic interest. An early diagnostic sign, and one upon which a great deal of reliance may be placed, is the presence of *stiffness in the joint* or of *limitation of motion* when the limb is manipulated. Limitation can be noticed early in the disease, unless the focus is remote from the joint. The restriction of motion is not the result of adhesions or beginning ankylosis early in the disease, but is caused by a tonic contraction of the muscles which control the joint. Slight degrees of stiffness may be revealed by comparing the resistance in one limb with that in the other or, particularly, by flexing the thigh at a right angle to the body and placing it in extreme abduction and external rotation. A change in the arc of any motion of the joint should arouse suspicion of disease in the joint. In the later stages of tuberculosis complete stiffness in the joint may occur. Stiffness from muscle spasm disappears, in a measure, under complete anesthesia. Intermittent *limping* is an important sign, but its absence does not exclude hip joint disease.

After the onset of inflammatory changes within the joint the limb adopts a characteristic attitude. It is flexed moderately, abducted, and rotated outwardly at the hip. This position permits the maximum relaxation and the greatest fluid content of the capsule, and therefore is the position of greatest ease. Any attempt to extend the limb is resisted strongly by the contraction of the muscles about the joint, since the effect of extension is to tense the iliofemoral ligament tightly over the front of the joint and to press the head of the femur against the acetabulum. The pressure causes acute pain.

In the standing position the weight of the body is borne mainly on the healthy limb to avoid pain from weight-bearing on the affected limb. The eversion of the foot is the index of external rotation. The affected leg characteristically is placed in advance of the sound one, and there is bending at the groin. Tilting of the pelvis may or may not be apparent, but can be demonstrated by careful examination. There is a change in the gluteal folds and in the buttocks. The gluteal fold on the diseased side is shorter and lower in position as a result of the downward tilt of the pelvis on that side; the buttock is flattened.

The attitude assumed by the patient in lying on a flat surface is characteristic. In order to bring the flexed thigh into contact with the surface, the spine is arched forward in the dorsolumbar region (lordosis) (p. 763). The pelvis on the affected side is tilted downward to bring the affected limb into contact with the sound one. The transverse axis of the pelvis, as indicated by a line through both anterior superior iliac spines, is oblique. This causes the limb on the affected side to appear longer than the other, although careful measurement reveals no actual difference. The amount of fixed flexion of the limb may be determined by the Thomas test (Fig. 889): the hip and knee of the sound limb are flexed passively until the thigh comes to rest against the abdomen. This maneuver throws the affected thigh into flexion deformity. The angle formed by the axis of the affected thigh with the table denotes the extent of permanent flexion.

If destruction within the joint continues, the attitude of the limb undergoes a change. Flexion at the hip continues, but the limb exchanges a position of abduction and external rotation for one of adduction and internal rotation. The changes in position probably are dependent upon the softening or relaxation of the ligaments, upon the destruction of the head of the femur and the acetabulum asso-

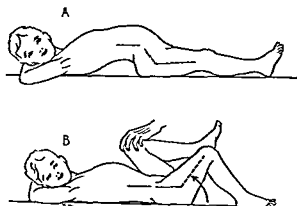


Fig. 889. THOMAS TEST FOR THE DEGREE OF FLEXION DEFORMITY IN FIXATION OF THE HIP IN TUBERCULOSIS.

The degree of flexion deformity can be determined only after the compensatory lumbar lordosis has been obliterated; forced flexion of the sound thigh on the abdomen obliterates the lordosis.

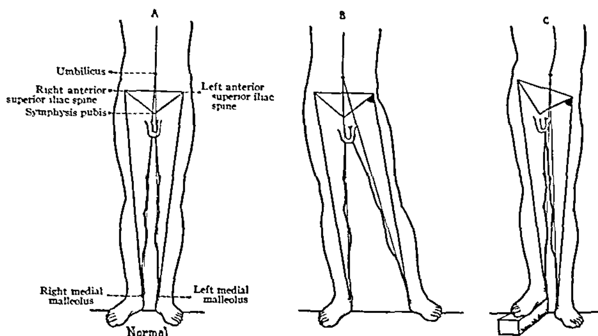


Fig. 888. DIAGRAMS ILLUSTRATING APPARENT LENGTHENING IN THE LEFT LOWER LIMB IN WHICH THE HIP IS FIXED IN ABDUCTION, EITHER BY MUSCLE CONTRACTION OR BY ANKYLOSIS. THERE IS NO ACTUAL OR BONY SHORTENING IN EITHER LOWER EXTREMITY.

A, Normal person, in whom there is no actual or apparent lengthening. *B*, The left thigh is fixed in abduction. The actual or bony measurements of the 2 lower limbs, taken from the anterior superior iliac spines, are equal, but the apparent measurements, taken from the umbilicus to the medial malleoli, show that the abducted limb is apparently lengthened. It is obvious that the abducted left leg cannot be brought to parallel the right leg in walking, unless the pelvis is tilted upward on the sound side. *C*, Block is placed under the sound lower extremity, and the pelvis is depressed markedly on the affected side. The apparent lengthening of the abducted leg is very marked.

amount of abduction. The illusion as to the actual inequality in the length of the limbs is dispelled by comparing the measurements taken from the umbilicus to the medial malleoli with those taken from the anterior superior iliac spines to the medial malleoli.

If the *lower limb is fixed in adduction*, there is, functionally, a shortening of the adducted leg caused by upward tilting of the pelvis on the affected side. Locomotion is facilitated by performing an osteotomy on the affected femur and placing it in abduction, or by elevating the adducted limb with a block. Fixation of the lower limb in abduction causes a downward tilting of the pelvis and functionally a lengthening of the affected extremity. Locomotion is made possible by elevating the sound limb with a block. The tilting of the pelvis produces a scoliosis in the lumbar spine.

TUBERCULOSIS OF THE HIP. Tuberculosis of the hip originates most frequently as an osteomyelitic lesion in the neck of the femur close to the epiphysial cartilage of the head of the bone, but rarely it may begin in the synovia. Primarily, the disease is intracapsular and almost always is extrasynovial, so that infection of the hip joint occurs with great frequency. In the progress of the disease the infection reaches the surface of the bone, destroys the periosteum, and invades the synovia. A joint effusion usually accompanies these changes. If effusion develops early, adhesions may form between the synovia lining the capsule and that on the femoral neck, and delay further extension of the disease into the joint. Adhesions cause limitation of motion, which may be the first sign of disease. If adhesions do not form, the lesion erodes the articular cartilage and becomes intrasynovial. The initial lesion rarely erodes the epiphysial cartilage without first involving the joint.

The focus may be at the diaphysial side of the epiphysis of the greater trochanter and may spread down the shaft as an osteomyelitis. The caries may ascend along the neck and ultimately involve the joint or, rarely, may break through the periosteum outside the joint, forming an abscess and, subsequently, a sinus. The tuberculous process may develop in any of the three components of the acetab-

cially when the tuberculosis originates in the acetabulum. The direction of *intrapelvic spread* depends upon whether the infection pierces the pelvic wall above or below the line of origin of the levator ani muscle (p. 584). In the first instance the pus erodes the parietal pelvic fascia and is free to extend in the extraperitoneal space of the pelvis. It may travel down along the rectum or fill up the pelvis until it overflows through the obturator foramen or escapes forward into the thigh behind the inguinal ligament. When the hip joint abscess pierces the pelvic wall below the origin of the levator ani, the pus invades the ischiorectal fossa and points near the anus. A collection of pus on the pelvic aspect of the acetabulum may be recognized by digital rectal examination. If the abscess results in sinus formation, the clinical picture becomes one of mixed infection. The roentgenogram then may show areas of new bone formation and sequestration. These findings are absent in uncomplicated tuberculosis.

Pyogenic osteomyelitis, that devastating disease peculiar to shafts at their metaphysial extremities, must be differentiated from tuberculosis. Pyogenic osteomyelitis frequently invades the neck of the femur, which is the superior and medial continuation of the shaft. The lesion is intra-articular by virtue of the capsular attachment, and is propagated swiftly to the synovia and to the other joint structures. Pyogenic osteomyelitis destroys the joint in a graver and more septic manner than does tuberculosis. It is accompanied by prostration, pyrexia and marked leukocytosis. The roentgenogram shows no bony changes in the acute stages, but shows areas of new bone formation late in the disease. Early radical drainage is imperative.

Injuries of the Upper Extremity of the Femur in General. In the *infant* the cartilaginous upper extremity of the femur, which includes the head and neck, may be fractured. The fracture may occur when the infant, held upright, throws itself backward so that the body weight stretches the strong iliofemoral ligament across the anterior surface of the head and neck of the femur. When the limbs are held firmly, the neck of the femur gives way, since the restraining ligament is too strong to yield; if the limbs are not held firmly, the backward thrust of the body weight on the iliofemoral ligament flexes the thigh and relieves the strain.

In a *child*, injury about the upper extremity of the femur may result in a greenstick fracture, as the cartilaginous neck is undergoing ossification. This lesion probably is one of the most frequent causes of coxa vara. In *later childhood*, separation of the epiphysis of the femoral head sometimes occurs. The diagnosis of this condition is important lest the epiphysis be allowed to unite in a faulty position and result in subsequent limitation of motion.

In vigorous *middle life*, dislocation of the head of the femur is the commonest severe lesion. In *later life* trivial trauma may cause fracture of the neck of the femur.

Epiphysial Separation of the Proximal Extremity of the Femur. Separation of the capital epiphysis of the femur usually does not occur in childhood, when the epiphysis is cartilaginous, but does occur in adolescence, when the epiphysis is bony and is uniting with the neck (Fig. 891). As a rule, separation occurs from minor trauma and from a stumble in which the leg is hyperextended. Separation frequently occurs in overweight children of the Froelich type (dystrophia adiposogenitalis), in whom ossification is delayed. The iliofemoral (Y) ligament holds the neck of the femur forward, and the epiphysis is levered from its position. If the displacement is partial, there is a persistent limp, slight shortening, limitation of abduction and internal rotation, and excessive external rotation.

Separation of the capital femoral epiphysis is not a rare condition and must be the first consideration in the differential diagnosis in an adolescent boy or girl who complains of pain in the hip or pain in the knee and a limp.

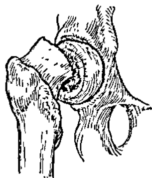


Fig. 891. SEPARATION OF THE CAPITAL EPIPHYSIS OF THE FEMUR.

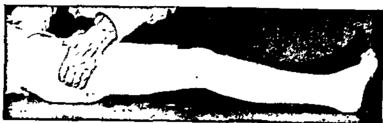


Fig. 890. METHOD OF PALPATING THE GREATER TROCHANTER.
(From Scudder: Treatment of Fractures.)

ciated with a weakness of the external rotator muscles, and upon excessive action of the adductor muscle group. If the patient lies on a flat surface, it is necessary to raise the pelvis on the diseased side in order to bring the adducted limb alongside its fellow. The transverse axis of the adducted limb, as indicated by a line joining the anterior superior spines, is oblique, but the obliquity is inclined in the opposite direction from that noted in the first stage. With the obliquity of the later stage of the disease, the affected limb appears to be shortened, but measurement reveals no actual shortening.

After the disease has caused a dislocation of the partially disintegrated head of the femur and advanced dissolution of the acetabulum, there begins a stage of real shortening of the limb. The head of the femur is dislocated upward and backward on the dorsum of the ilium, while the limb remains flexed, adducted, and rotated medially. This position is assumed by the limb in spontaneous cure. Real shortening is not, of necessity, an indication of dislocation, but may be the result of absorption of the head of the femur and widening of the acetabulum. Eventually the displaced femur may become ankylosed firmly to the ilium, and the acetabular cavity may be filled with granulation tissue.

Pain is an important, though rarely an early, symptom. It may be in the hip, but often is referred to the medial or anterior aspect of the knee. This reflex phenomenon is intelligible when it is recalled that both joints are innervated from the femoral (p. 959) and obturator (p. 983) nerves. In time the muscle spasm becomes increased to a degree which fixes the disorganized articular surfaces, and relaxes only during sleep. Night cries, typically coming before midnight, when sleep is most profound, are caused by the momentary pain resulting from movements of one eroded bone against the other, permitted by the relaxation of sleep. The muscle spasm tends to create permanent deformity, because the position assumed by the limb is not a functional one, but is dictated by the most powerful group of muscles.

Abscesses in Tuberculosis of the Hip and Their Paths of Extension. Tuberculosis of the hip almost always becomes intrasynovial; therefore suppuration in the joint is the rule rather than the exception. The effusion may cause a slight fullness in the femoral triangle (of Scarpa) just inferior to the inguinal ligament and beneath the femoral vessels. The pus eventually perforates the capsule at its weakest points, which are posterolateral and anterior, but it may spread into the pelvis.

If the exit is posterolateral or posterior, the pus at first collects between the gluteal muscles and the lateral surface of the ilium. It apparently finds no obstacle to forward progress, for it usually travels anteriorly deep to the gluteus maximus and tensor fasciae latae muscles to point in the interval between the tensor fasciae latae and the sartorius muscles. The abscess may travel backward, however, and point in the gluteal region at the transverse gluteal fold.

The path taken by pus which has *perforated the anterior part of the capsule* is not constant. If the joint communicates with the iliopsoas bursa, the pus may ascend within the bursa to the iliac fossa or may enter the sheath of the iliopsoas muscle. Pus may descend along the iliopsoas tendon, follow the course of the medial circumflex artery, reach the dorsum of the thigh over the upper border of the adductor magnus muscle, and point at the gluteal fold; or it may pass laterally along the lateral circumflex artery and become superficial near the gluteal fold or near the greater trochanter.

Occasionally the abscess makes its way through the acetabulum into the pelvis, espe-

tion after proper reduction. Proper reduction is most important, and this means complete reduction in the lateral position and a valgus position in order to place the head in a position of impaction on the femoral neck. Internal fixation can then be carried out by any of the accepted supports which are in common use, such as the Smith-Petersen nail, screws, threaded wires and blade plates, any one of which can be satisfactorily used if the reduction is proper and the fixation is adequate. With satisfactory internal fixation the patient can be got out of bed into a chair or in a walker or on crutches within a few days, or at most within a few weeks, and the complications of prolonged bed care are avoided. Because of the ability to avoid the complications of prolonged immobilization in these patients, internal fixation and surgery is the conservative treatment for fractures about the hip, almost regardless of the age or the general condition of the patient. The surgical correction is not an emergency procedure, but if at all possible should be done within forty-eight hours after the fracture. Shortening after such treatment is negligible in most cases. Occasionally the use of a subtrochanteric osteotomy in order to assure a valgus position of the head of the femur where the fracture shaft angle is acute, or perhaps the addition of a bone graft across the fracture site in addition to the internal fixation pin is indicated.

During recent years in the elderly person, that is, the person over seventy years of age, who has a subcapital fracture of the femur the use of one of the stem prostheses, such as the Austin-Moore type of prosthesis, to replace the femoral head has proved satisfactory. This permits early ambulation and assures a comfortable, freely movable, stable hip joint.

INTERTROCHANTERIC AND PERTROCHANTERIC FRACTURES. *Intertrochanteric fractures* are similar in cause and displacement to fractures at the base of the femoral neck. The fracture line follows the anterior oblique intertrochanteric line, and usually is impacted with slight displacement of the fragments. The spongy vascularity of the bone at this level is conducive to bony union, but some degree of coxa vara is likely to ensue.

A *pertrochanteric fracture* usually passes through the base of the neck or upper part of the shaft, distal to the greater trochanter and proximal to the lesser trochanter (Fig. 893). The treatment is similar to that for intertrochanteric fracture.

TRAUMATIC DISLOCATION OF THE HIP. Traumatic dislocation of the hip is comparatively rare because of the great stability the hip derives from its powerful capsule and from the strong muscles surrounding it. The joint is particularly secure above, in front and behind, because the socket of the acetabulum is deep, and the rim is strong at these points. At its lower part the acetabular cavity is comparatively shallow, and part of its rim is deficient.

POSTERIOR DISLOCATION is produced by indirect violence applied through the feet, legs or back when the thigh is flexed, adducted, and rotated medially. This injury is not uncommon as the result of an automobile accident with the patient sitting particularly in the front seat of the car; as the result of a head-on collision the knee is driven against the dashboard. In this position the femoral shaft is the long arm of the lever, the iliofemoral (Y) ligament is the fulcrum, and the neck is the short arm of the lever. The head is forced against the posterior part of the capsule, tears it, and passes upward and backward on the dorsum of the ilium, superior to the tendon of the obturator internus muscle; it may occupy an iliac or a sciatic position. The short rotator muscles of the femur, particularly the obturator internus muscle, are liable to injury. The strongest part of the capsule, the iliofemoral (Y) ligament, usually is not ruptured, but the posterior capsule is torn widely. The tendon of the obturator

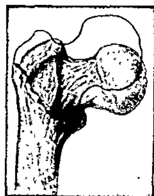


Fig. 893. PERTROCHANTERIC FRACTURE OF THE FEMUR.

(From Babcock: Textbook of Surgery.)

Many times there is no definite history of injury, particularly one that is disabling. A diagnosis can frequently be made by examining the gait of the child who walks with a definite limp and with external rotation of the involved extremity. On flexion of the hip of the affected side, either with the child standing or lying, the leg immediately goes into external rotation rather than flexes in a neutral position. Radiographic examination is most important; and in minimal slips the anteroposterior view of the hip, which, of course, should include the pelvis to compare with the opposite side and with both legs held in maximum internal rotation, may show little, if any, demonstrable deformity of the hip. The lateral projection of the hip is the most important view, and a diagnosis of a slipped femoral epiphysis cannot be ruled out merely with a single anteroposterior x-ray film. Invariably the head of the femur assumes an inferior and posterior position.

It is important that treatment of this condition be started immediately upon diagnosis. The slip will progress and assume a serious deformity of the hip without treatment. If the condition is found early before more than minimal deformity has occurred, internal fixation in situ of the femoral head on the femoral neck with multiple pins, and the use of crutches until the epiphysial plate is closed, will prevent further deformity and lead to normal hip function. If the slip is more than minimal, open reduction with a careful replacement of the head in a valgus position and internal fixation is the most satisfactory method of treatment to date. The operation itself, however, is difficult and delicate and should be performed only by those skilled in hip joint surgery.

FRACTURE OF THE NECK OF THE FEMUR. Fracture of the neck of the femur usually occurs in persons over sixty, particularly in women. When fracture occurs at a high level (subcapital), the blood supply to the head of the femur from the neck is damaged. The supply by way of the ligamentum teres frequently is inadequate. When fracture occurs at a lower level, part of the posterior capsule is usually left attached to the proximal fragment, affording it, at best, a feeble blood supply.

The cause of fracture may be a stumble, a fall or, in vigorous adults, a fall upon the greater trochanter. It may also be occasioned by exaggerated movements at the hip joint. The line of fracture may be just below the head, through the middle of the neck or just above the trochanters (Fig. 892). The closer the break is to the head of the femur, the less ligamentous attachment is left upon the proximal fragment, and the poorer is the prospect of repair. The more extensive the ligamentous attachment to the proximal fragment—that is, the farther toward the trochanter the neck is divided—the more adequate is the blood supply, and the better is the chance of union.

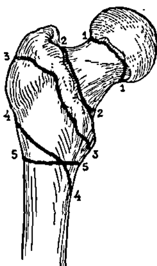


Fig. 892. LINES OF FRACTURE IN THE UPPER EXTREMITY OF THE FEMUR.

1, Subcapital fracture of the neck of the femur; 2, fracture through the base of the neck; 3, pertrochanteric fracture; 4, oblique subtrochanteric fracture; 5, transverse subtrochanteric fracture.

When the greater trochanter ascends, after fracture of the femoral neck, that portion of the fascia lata which stretches between this prominence and the iliac crest becomes relaxed unduly, so that the tenseness or resistance of the tissues to pressure immediately above the trochanter is less on the injured side than on the sound side. The limb lies in helpless eversion. This depends to some extent on its tendency to roll outward under the influence of gravity, and to the action of the external rotator muscles, which are stronger than the medial rotators.

The accepted treatment for fractures of the neck of the femur, including subcapital fractures, intracapsular fractures, basilar neck fractures, intertrochanteric fractures and subtrochanteric fractures, is that of internal fixa-

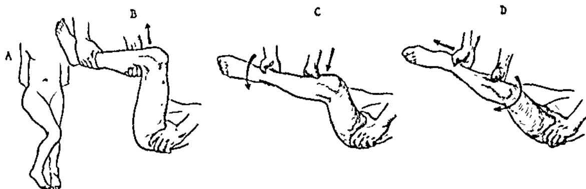


Fig. 896. BIGELOW'S METHOD OF REDUCTION OF A POSTERIOR DISLOCATION AT THE HIP.

A, The deformity in posterior dislocation. *B*, Upward traction is exerted upon the flexed limb; the pelvis is steadied by an assistant. *C*, The flexed limb is abducted while the pelvis is steadied. *D*, The flexed and abducted limb is rotated laterally; the last step consists in extending the limb.

ment which keeps the limb flexed and adducted. This tension acts powerfully when an extending force is applied to the limb. To obviate this, the first step in reduction consists in flexing the thigh on the pelvis and adducting the limb, since these movements tend to disengage the head of the femur and enable it to be brought along the inclined plane posterior to the acetabulum toward the opening in the capsule. The thigh is then abducted and rotated laterally to bring the head of the femur opposite its socket. This movement renders the relaxed iliofemoral ligament tense, so that it may be used as the fulcrum of the lever, which has the femoral shaft for its long arm and the neck for its short arm. The movement of lateral rotation levers the head forward over the posterior margin of the acetabulum. By completing the circumduction and extending the limb, the head is made to travel medially and upward into the socket.

In *Stimson's gravity or postural method of reduction of posterior dislocation of the hip* the patient is placed face downward upon a table with his legs projecting beyond the edge of the table. The normal limb is held horizontally by an assistant while the injured thigh extends directly downward. The ankle of the injured limb is grasped, and the knee is flexed to a right angle (Fig. 897). The weight of the limb, in addition to that of a sandbag placed upon the flexed half just below the knee, furnishes the necessary traction in the desired direction. The position is maintained until the muscles relax. The bone usually is felt to slip into place with no more manipulation than a slight rocking of the limb.

ANTERIOR DISLOCATION results from violent abduction of the thigh. The head of the femur leaves the inferomedial part of the socket and passes forward and mesially to rest upon the obturator foramen (obturator or thyroid dislocation), or reaches an even more anterior position beneath the pubis (pubic dislocation) (Fig. 894).

In *dislocation into the obturator foramen* the femur comes to rest on the obturator externus muscle. The iliofemoral ligament is not torn, and, in conjunction with the iliopsoas muscle, it helps to maintain the limb slightly flexed, abducted, and rotated outward. The greater trochanter is depressed and is less prominent than on the sound side, and its upper extremity impinges on the lower border of the acetabulum.

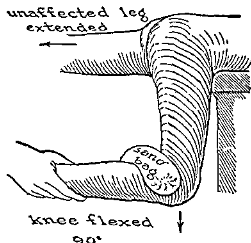


Fig. 897. STIMSON'S METHOD OF REDUCING A POSTERIOR DISLOCATION OF THE HIP.
(From Babcock: Textbook of Surgery.)

internus muscle may be interposed between the neck of the femur and the socket. There may be damage to the sciatic nerve.

In the iliac variety of posterior dislocation the femoral head lies on the dorsum of the ilium (Fig. 894) and can be felt in the buttock. The thigh is flexed, adducted, and rotated inward, a position which is determined mainly by the tension of the iliofemoral ligament and the direction of the inclined plane against which the head and neck of the femur rest. The foot is inverted, and the heel sometimes rests on the dorsum of the opposite foot. Flexion of the thigh is marked when the femoral head remains low, but is slight when it is high on the ilium (the usual position). With this upward displacement of the femur, shortening is always present; the amount may be estimated readily by noting how far the summit of the greater trochanter projects proximal to Nélaton's line. There is a noticeable alteration in the contour of the hip: the normal depression behind the trochanter is obliterated; the gluteal fold is raised; there is an unusual fullness of the buttock; and it may be possible to feel the head of the femur or the trochanter beneath the gluteus maximus muscle. Abduction and external rotation of the thigh are impossible. The deformity of *sciatic dislocation* (into the sciatic notch) is similar to, but less noticeable than, dislocation on the dorsum of the ilium, and the mode of production is similar (Figs. 894, 895). Flexion and inversion of the thigh sometimes are more marked in sciatic dislocation, in which the head of the femur rests upon the back of the ischium, close to its spine, partially overlies the two sciatic foramina, and lies below the tendon of the obturator internus muscle.

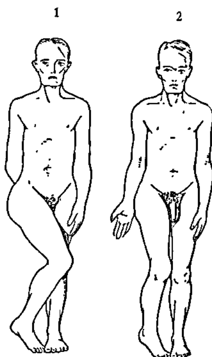


Fig. 895. ADDUCTION DEFORMITY IN POSTERIOR DISLOCATION OF THE HIP.

1, Dorsal (iliac) dislocation. 2, Ischial (sciatic) dislocation. (From Babcock: Textbook of Surgery.)

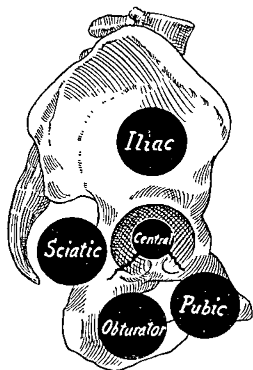


Fig. 894. LOCATION OF THE HEAD OF THE FEMUR IN THE COMMONER VARIETIES OF DISLOCATION OF THE HIP.

(Eisendrath, in Keen's Surgery.)

A dislocation of the hip commonly may be overlooked when there is an obvious fracture of the shaft of the femur. In such a case a dislocation of the hip must be suspected if the proximal shaft of the femur is held in an adducted and flexed position. Such deformity of the proximal fragment would be most unlikely to be present without a dislocation of the hip.

In the *Bigelow method for the reduction of posterior dislocation of the hip* the head of the femur is made to retrace its course through the tear in the capsule (Fig. 896). The main obstacle to the reduction of posterior dislocation is the tension of the iliofemoral (Y) liga-

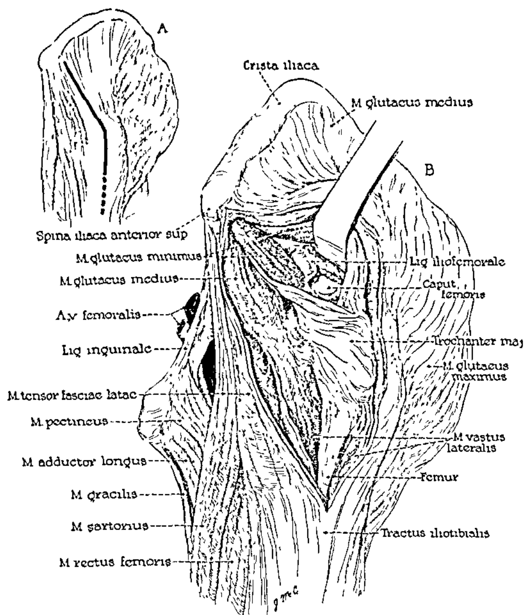


Fig. 899. LATERAL APPROACH TO THE HIP JOINT (WATSON-JONES).

A, A slightly curved incision is made, beginning 1 inch below and lateral to the anterior superior iliac spine, and extending downward and posteriorly over the lateral aspect of the greater trochanter and the lateral shaft of the femur to 2 inches below the base of the trochanter. *B*, The interval between the gluteus medius and tensor fasciae femoris muscles is located and dissected, and the muscles separated. The capsule of the joint is incised longitudinally along the anterosuperior surface of the neck of the femur.

If a more extensive exposure is necessary, the anterior fibers of the gluteus medius may be detached from the trochanter, and the anterior superior portion of the greater trochanter may be separated with an osteotome and reflected with the insertion of the gluteus medius muscle. In the lower portion of the incision the vastus lateralis origin may be reflected downward or split longitudinally to expose the base of the trochanter and proximal segment of the shaft of the femur.

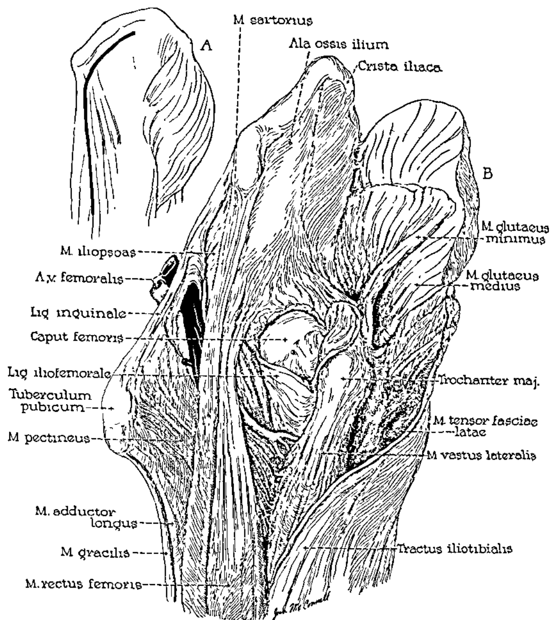


Fig. 898. ANTERIOR ILIOFEMORAL APPROACH TO THE HIP JOINT (SMITH-PETERSEN).

A, The skin incision is made from the middle of the crest of the ilium forward to the anterior superior iliac spine and then downward for 4 to 5 inches. *B*, The superficial and deep fasciae are divided, and the attachments of the gluteus medius and tensor fasciae femoris are severed from the iliac crest. Subperiosteally, the attachment of the gluteus medius and minimus muscles is stripped from the external surface of the ilium, and anteriorly the dissection is carried between the tensor fasciae latae and the sartorius and rectus femoris muscles. One inch below the anterior superior spine the lateral femoral cutaneous nerve will be found as it passes over the sartorius, and should be retracted medially. With the gluteus medius and tensor fasciae latae muscles reflected downward and backward, the joint capsule is exposed. The ascending branch of the lateral femoral circumflex artery is encountered 2 inches below the hip joint and should be ligated. In opening the joint capsule transversely, the iliofemoral ligament on the anterior portion of the joint capsule should be preserved. The head of the femur and upper margin of the acetabulum are now well in view, and by severing the ligamentum teres the head may be dislocated, giving good access to all parts of the joint.

Dislocation upon the pubis is an advanced form of obturator dislocation (Fig. 894). From its primary position inferior and slightly anterior to the acetabulum, the head of the femur advances forward and upward in front of the horizontal ramus of the pubis, opposite the iliopectineal eminence. It is impelled in this direction and to this position by a powerful everting action applied to the limb. The head of the femur may cause the iliopsoas muscle to project inferior to the inguinal ligament, carrying forward with it the femoral vessels and the femoral nerve. The iliopsoas and pectineus muscles may be lacerated, and the obturator and femoral nerves may be stretched or torn. The thigh is flexed, abducted, and rotated externally. *Flexion results from contraction of* the iliopsoas muscle.

In the *reduction of anterior dislocation* the thigh is flexed to a right angle and abducted to disengage the head of the femur. The thigh then is lifted, rotated medially, and extended so that the head of the femur may be made to retrace its path to the postero-inferior part of the acetabulum.

Intrapelvic or central dislocation of the head of the femur is a penetrating fracture of the acetabulum. Routine radiographic examination has demonstrated that it is not an unusual injury. The lesion occurs when a fall upon the hip drives the femoral head so violently into its socket as to fracture the acetabulum. It is an accident of vigorous middle age and is unlikely to occur in the elderly, in whom the femoral neck usually fractures before the head can damage the acetabulum. A radiating fracture of the acetabulum occurs with depression of the socket and a bulging inward of its central part. The socket may remain intact and be driven in as a whole. The head of the femur seldom is driven deeply into the pelvis.

The condition must be differentiated from ordinary dislocation and from fractures through and about the femoral neck. An impacted fracture through the neck of the femur or a trochanteric fracture at the base of the neck may closely resemble fracture of the acetabulum with central dislocation. In the latter condition rectal examination should reveal the characteristic inward displacement of the acetabulum. The fracture-dislocation is reduced by downward traction upon the leg, combined with an outward pull upon the upper thigh.

Surgical Approaches to the Hip Joint. During recent years there have been many descriptions of new surgical approaches to the hip joint, but most of these have been devised *for a specific procedure or objective.* The most widely used are the anterior iliofemoral incision as described by Smith-Petersen (Fig. 898), lateral approach of Watson-Jones (Fig. 899), and the posterolateral approach of Gibson (Fig. 900).

The complete Smith-Petersen incision gives an excellent exposure through which virtually all operations on the hip joint can be carried out (Fig. 898). Separate portions may be used for special purposes, such as using the anterior femoral incision for simply exposing the joint. This would be inadequate for reconstructive measures. For extensive arthroplasty of the hip, Smith-Petersen has modified and improved the approach by reflecting the iliacus muscle from the medial surface of the anterior portion of the ilium, and by detaching the rectus femoris muscle from its origin.

The Watson-Jones lateral approach to the neck of the femur and hip joint (Fig. 899) necessitates removal of the greater trochanter with the insertions of the gluteus medius and minimus muscles. Adequate exposure is provided for treatment of fractures of the neck of the femur. It is also widely used for osteotomies, bone graft procedures and for the

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A, The patient is placed on the operating table in either a prone or lateral recumbent position. The incision first follows the lateral margins of the gluteus maximus muscle from a point near the posterior superior iliac spine to the greater trochanter, before it turns vertically downward over the thigh for approximately 4 inches. The skin margins are adequately mobilized and retracted. *B*, The junction of the gluteus maximus and medius is located by palpation, and the overlying fascia is opened by sharp dissection. The incision then is continued distally through the fascia lata along the posterior margin of the tensor fasciae latae (iliotibial tract). *C*, The gluteus maximus is drawn medially. The fascia lata is retracted laterally to expose the gluteus medius muscle, as well as the lateral surface of the greater trochanter and the proximal portion of the vastus lateralis distal to it. A pad of fat deep in the wound separates the gluteus maximus and medius muscles. The sciatic nerve lies deep and medially to the gluteus maximus and need not be exposed if the dissection is to be confined to the immediate area of the hip joint. (From Banks and Laufman: An Atlas of Surgical Exposures of the Extremities.)

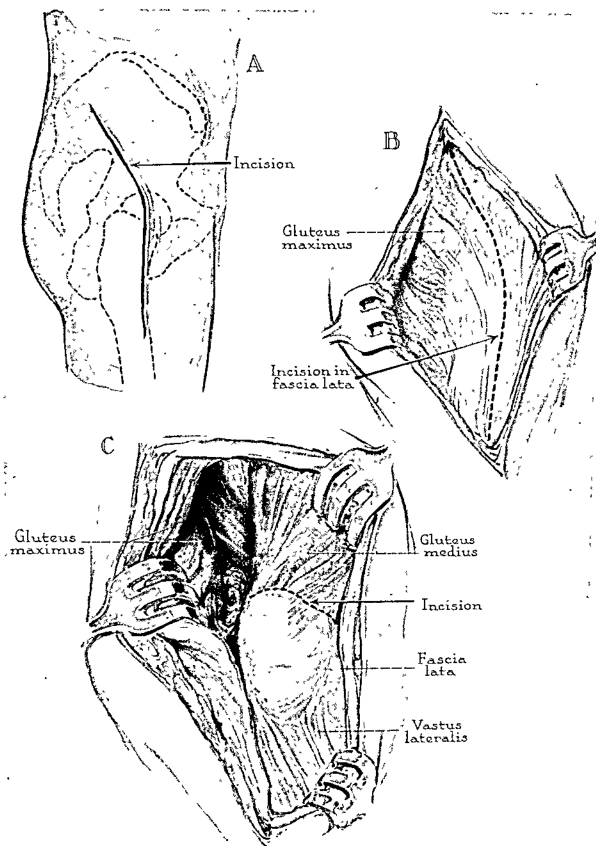


Fig. 900. POSTEROLATERAL APPROACH TO THE HIP JOINT AS MODIFIED FROM GIBSON.

(See legend on facing page.)

excision of intrinsic lesions in the proximal end of the femur.

The Gibson approach to the hip joint (Figs. 900, 901) is particularly valuable in the insertion of the replacement prosthesis for a subcapital fracture and has many other indications for arthroplasties and débridements of the hip joint, or in the placement of fractured fragments after a posterior or superior dislocation of the hip joint. The approach encounters a minimal amount of bleeding and deserves an important place in the practice of the surgeon who will be called upon to do hip joint surgery.

D, The tendons of the gluteus medius and minimus muscles may be cut at their attachment to the greater trochanter and retracted proximally, as shown, or the medius insertion may be reflected subperiosteally to give adequate exposure, with later more rapid recovery of active muscular function. The lateral and anterior surfaces of the capsule of the hip joint are now in the wound. The head of the femur can be exposed by an adequate incision through the capsule. *E*, Additional room can be obtained by tenotomy of the piriformis at its point of attachment to the greater trochanter. When maximum exposure is required, the obturator internus and the superior and inferior gemellus muscles may be separated from the greater trochanter with the scalpel.

This incision is becoming increasingly popular because it provides a wide exposure of the hip joint, with encounter of few vessels and no major nerves. The tendons are reattached as the wound is closed. (From Banks and Laufman: An Atlas of Surgical Exposures of the Extremities.)

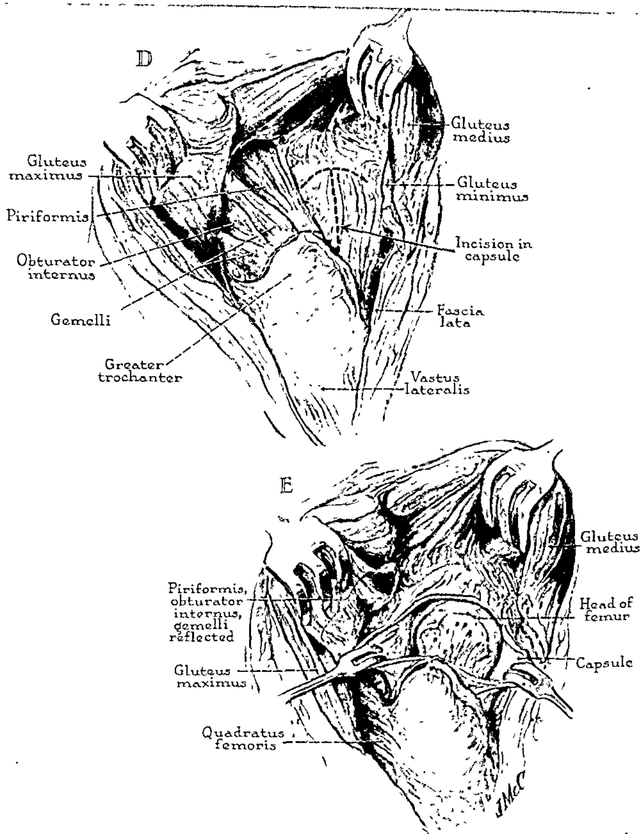


Fig. 901. POSTEROLATERAL APPROACH TO THE HIP JOINT AS MODIFIED FROM GIBSON (CONTINUED).

(See legend on facing page.)

sacroiliac regions, limitation of straight leg-raising, and functional scoliosis. The abnormal pull on the pelvic bones causes bad posture. The contracted portion lies usually between the crest of the ilium and the anterior aspect of the trochanter. Incision of the fascia lata in this area, when contracture is definite, improves the disturbances mentioned.

Contracture of the iliotibial band is probably one of the most deforming, single structures following poliomyelitis with partial paresis or paralysis to the lower extremity in a child and will lead to multiple fixed deformities unless the band is sectioned as soon as it is apparent that deformities are beginning, and that the band is contracted and not responding to stretching exercises. In this case section of the iliotibial band on the lateral side of the thigh approximately 2 inches above the femoral condyle with resection of approximately one inch width of the band and careful attention to section also of the intermuscular septum gives a satisfactory result in preventing further deformity.

From its deep aspect, sheathing septa extend between the muscles. The *lateral intermuscular septum* is a strong partition which connects the deep fascia with the lateral lip of the linea aspera on the posterior surface of the shaft of the femur. This septum separates the lateral vastus muscle from the femoral (short) head of the biceps muscle and demarcates the extensor and flexor regions of the thigh. The septum begins at the level of the lowermost insertion of the gluteus maximus muscle inferior to the greater trochanter, and terminates at the lateral aspect of the knee joint. The *medial intermuscular septum* is not as well defined as the lateral; it extends from the level of the lesser trochanter to the adductor tubercle, and separates the adductor and extensor muscle compartments of the thigh.

These septa enclose the thigh muscles in three osteofibrous compartments, each of which has its own nerve. The anterior or extensor group of muscles is supplied by the femoral nerve, the posterior or flexor group by the sciatic nerve, and the medial or adductor group by the obturator nerve.

The arrangement of the fascia lata at the root of the thigh and about the fossa ovalis is described on page 955. At the fossa the vascular relations vary between widely separated limits (Fig. 902).

It is apparent (Milgram and Prentiss) that there is a large anterolateral *fascial space* which runs the entire length of the thigh. This space communicates superiorly with a large posterior fascial area under the gluteus maximus muscle. In direct continuation with the subgluteal space is the fascial space which extends downward about the diverging hamstring muscles and tendons.

Pathogenesis of Infections within the Deep Fascial Spaces of the Thigh. Infections adjacent to the deep fascial spaces of the thigh may rupture into them. When these potential spaces are infected, pus or extravasations of blood may travel long distances and point in areas remote from the initial lesion.

Hematogenous infection may localize in the fascial spaces of the thigh. Hematomas from fracture of the neck of the femur may become infected, and the resulting abscess cavity may extend upward under the gluteus maximus muscle and downward into the anterior or posterior fascial spaces. Hematogenous infections in the posterior fascial space have often been observed without involvement of the popliteal space. Infected emboli may cause widespread infection of the fascial spaces.

Infections may be introduced directly into the fascial spaces by hypodermic injections and hypodermoclysis. Extraspatial purulent foci may extend into the deep spaces. Tuberculous abscess from the spine or sacroiliac joint, or retroperitoneal suppurating glands may involve these spaces. These purulent collections follow an anterior route beneath the inguinal ligament or a posterior path through the suprapiriform and infrapiriform foramina (p. 584). Lesions of the ilium which perforate the gluteus medius muscle may rupture into the posterior space and point far down the thigh. Lesions of the hip joint, the greater trochanter or the shaft of the femur may involve either the anterior or the posterior space. Among the intraspatial lesions which burrow down the fascial spaces are infected bursae and lymph nodes.

The complications of fascial space infection are extension from one space to another; persistent draining sinuses from inadequate drainage of the original focus or of the fascial compartment; and involvement of the vasculoneural element in the floors of the spaces. Femoral and sciatic nerve involvement is common, and femoral phlebitis and arterial thrombosis have been observed.

CHAPTER 35

Thigh

Thigh in General

BOUNDARIES AND DIVISIONS. The thigh is bounded above and in front by the fold of the groin which corresponds in direction to the inguinal ligament. Its upper limit posteriorly is the transverse gluteal fold. The lower boundary of the thigh is a plane three fingerbreadths above the base of the patella, a level which corresponds to the upper limit of the subquadriceps bursa (p. 1025).

The thigh is divided topographically into four regions: the inguinofemoral (root of the thigh), adductor (obturator), anterior (flexor) and posterior (extensor).

LANDMARKS. The general outline of the limb is conical, and the oblique direction of the long axis is downward and inward. The obliquity is greater in females than in males because of the greater proportional width of the pelvis. In females the general surface of the thigh is rounded uniformly by the great amount of subcutaneous fatty tissue. In vigorous adult males well developed muscles stand out in bold relief.

The sartorius muscle inclines downward and inward across the iliopsoas muscle from the anterior superior spine to its tibial insertion. It is rendered distinct by flexing the limb actively in outward rotation. The femoral trigone (of Scarpa) is the depression inferior to the inguinal ligament. In a well-muscled person a definite groove extends from the apical extremity of the femoral trigone along the medial aspect of the thigh toward the medial condyle of the femur, especially when the thigh is flexed and abducted. This groove indicates the demarcation between the vastus medialis muscle laterally and the adductor musculature medially. The sartorius muscle descends within this groove; the groove overlies the femoral vessels in the adductor canal. Immediately superior to the patella is the flat tendon of the rectus femoris muscle; medial to the patella is the rounded mass of the vastus medialis muscle. A groove runs upward and medially from the lateral margin of the patella to the middle of the thigh, and separates the rectus femoris muscle from the vastus lateralis. On the lateral side of the thigh is a longitudinal depression formed by the iliotibial tract of the fascia lata. In this area the deep fascia sends a partition inward to the linea aspera, the external (lateral) intermuscular septum which separates the flexor group from the extensor group of thigh muscles. In the upper two thirds of the posterior part of the thigh the hamstring muscles are grouped closely into a prominent mass. As they diverge toward the knee, the biceps and the semitendinosus tendons become prominent. These muscles form the boundary of the popliteal fossa proximally.

DEEP FASCIA (FASCIA LATA) AND FASCIAL SPACES. The sheathing or DEEP FASCIA of the leg is a well-defined aponeurotic membrane which completely invests the muscles of the thigh. In the lower part of the thigh it extends over the patella, the quadriceps tendon, and the capsule of the knee joint. It covers the popliteal space and binds together the muscles forming its margins.

The fascia lata varies in strength and thickness. It is unusually strong over the outer aspect of the thigh, where it is reinforced by the insertions of the tensor fasciae latae and gluteus maximus muscles. This part of the fascia lata, known as the *iliotibial tract*, stretches from the lateral margin of the iliac crest to the external condyle of the tibia. Over the lower part of the front of the thigh and over its medial surface the fascia is comparatively thin.

Ober contended that a *contracture of the iliotibial band* or of the lateral fascia lata in general causes limitation of motion, muscle spasm, tenderness over the lumbosacral or

sacroiliac regions, limitation of straight leg-raising, and functional scoliosis. The abnormal pull on the pelvic bones causes bad posture. The contracted portion lies usually between the crest of the ilium and the anterior aspect of the trochanter. Incision of the fascia lata in this area, when contracture is definite, improves the disturbances mentioned.

Contracture of the iliotibial band is probably one of the most deforming, single structures following poliomyelitis with partial paresis or paralysis to the lower extremity in a child and will lead to multiple fixed deformities unless the band is sectioned as soon as it is apparent that deformities are beginning, and that the band is contracted and not responding to stretching exercises. In this case section of the iliotibial band on the lateral side of the thigh approximately 2 inches above the femoral condyle with resection of approximately one inch width of the band and careful attention to section also of the intermuscular septum gives a satisfactory result in preventing further deformity.

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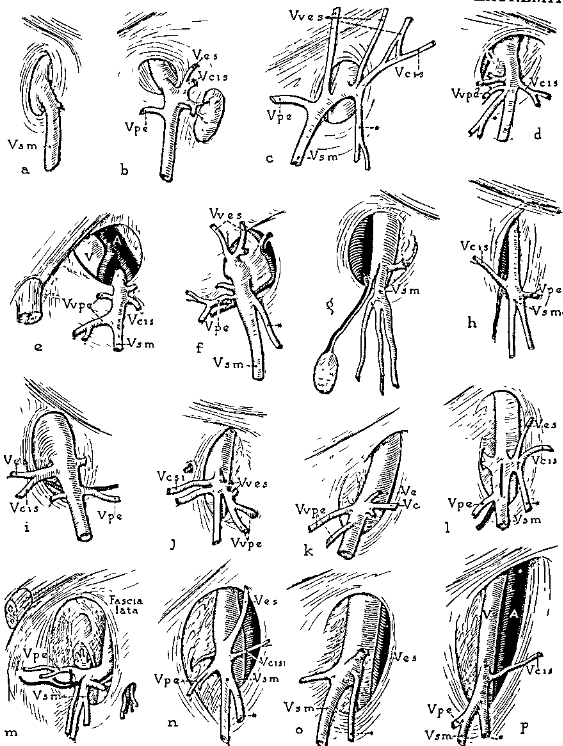


Fig. 902. FOSSA OVALIS AND CONTAINED BLOOD VESSELS; SELECTED EXAMPLES FROM 200 SPECIMENS.

In outline, the fossa is occasionally almost circular (*b* and *g*). Usually, however, it is oval (*a*, *d*, *h* to *m*); when thus compressed, the narrowness may be strikingly displayed (*h* and *j*). Occasionally the fossa is dart-shaped, with the pointed end directed downward (*n* and *p*). Within the space of the fossa proper accessory hiatuses not infrequently occur, transmitting muscular tributaries to the larger veins.

In size, the greatest variability is expressed. The smallest fossa in the 200 is 1.6 cm. in length, 1.7 cm. in width (*b*); the narrowest measures 1.0 cm. (*a*), the shortest 1.6 cm. (*b*). The largest fossa in the group is 8.5 cm. in length, 3.5 cm. in width (*p*). Ninety per cent of the specimens (i e., 180 fossae) measured between 3 0 and 6 4 cm. in length; 53.5 per cent (107 fossae) measured between 3.5 and 5.4 cm. The average length is 4 6 cm. In width, 87 per cent (174 fossae) are between 1.5 and 3.9 cm.; 70.5 per cent (141 fossae) are between 1.5 and 3.9 cm.; 70 5 per cent (141 fossae) are between 2.0 cm. and 3.9 cm. The average width is 2.8 cm.

(*Legend is continued on facing page.*)

Efficient treatment consists in accurate preoperative localization followed by drainage of the primary focus, and adequate drainage of the fascial space or spaces involved. The anterior fascial compartment may be incised widely through an incision begun behind the greater trochanter, because only the subcutaneous tissue and the deep fascia are encountered. The incision can be extended downward and forward almost the entire length of the thigh.

When the lesion is in the posterior space about the greater trochanter, the upper two thirds of the fibers of the gluteus maximus tendon should be divided near their insertion on the trochanter. Simple splitting of the gluteus maximus muscle is likely to be unsatisfactory, since drainage becomes blocked in a short time. The principles and details of the treatment by packing and immobilization are adapted to these infections.

Inguinofemoral or Subinguinal Region

Definition and Boundaries. The inguinofemoral region includes the soft parts at the root of the thigh. It is bounded above by the inguinal ligament, medially by the pectineus muscle, and laterally by the tensor fasciae latae muscle. Its lower boundary is an artificial horizontal line passing through the apex of the femoral triangle (Fig. 903).

Landmarks. In a well-muscled male the muscles in this region are prominent, especially when the hip and knee joints are flexed and the limb is rotated laterally. In this attitude the surface of the thigh is flattened or depressed for some distance below the inguinal ligament. From the distal part of the flattened area two muscle prominences diverge upward. The medial prominence corresponds to the pectineus and adductor longus muscles. The medial margin of the adductor longus becomes distinct when the thigh is adducted against resistance. Its rounded tendon can be felt and traced to the pubic tubercle, even in obese persons. The sartorius muscle forms the lateral prominence. The area included between these muscles and the inguinal ligament is known as the femoral trigone (triangle of Scarpa).

Within the femoral triangle the femoral artery and often the superficial subinguinal lymph nodes are palpable. The inguinal ligament forms a ridge passing from the anterior superior spine to the pubic tubercle. The location of the tubercle is utilized in differentiating between a femoral and an inguinal hernia. The neck of a femoral hernia lies inferior to the tubercle, while that of an inguinal hernia lies superior to it.

Lateral to the sartorius muscle, and just distal to the anterior superior spine, is a triangular depression, the outer boundary of which is the tensor fasciae latae muscle and the anterior superior spine. This depression overlies the proximal part of the rectus femoris muscle; this in turn overlies the capsule of the hip joint. In forced extension of the thigh combined with outward rotation, a fullness representing the head of the femur projecting against the front of the capsule appears in this depression. Through this depression the incision for the anterior approach to the hip joint is usually made (p. 947). The surface projection of the femoral artery is a line from the midpoint of the inguinal ligament to the adductor tubercle when the knee is flexed, abducted, and rotated laterally.

Superficial Structures. The subcutaneous tissue usually contains a considerable amount of fat within its meshes. Near the inguinal ligament the subcutaneous tissue is arranged in two layers continuous with those over the lower abdominal wall. The three *superficial branches of the femoral artery* arise in this region. The superficial epigastric and the superficial external pudendal arteries have been described (p. 960). The superficial circumflex iliac artery pierces the deep fascia lateral to the fossa ovalis and passes laterally. These small arteries are accompanied by corresponding veins which join the great saphenous vein close to its termination (Fig. 685, p. 718).

The *great saphenous vein* runs in the superficial fascia on the anteromedial part of the

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Without exception fossae were capacious for the vessels which they transmit. Regularly a considerable space, unoccupied by vessels, was included between the cornua of the fossa (*j* and *p*), the size of contents in no way affecting the proportions of the orifice. Moreover, in 83 per cent of 100 consecutive cases the femoral artery, also, is wholly or partially exposed.

Abbreviations: *V.s.m.*, vena saphena magna; *V.e.s.*, vena epigastrica superficialis; *V.c.i.s.*, vena circumflex ilium superficialis; *V.p e.*, vena pudenda externa. Asterisk indicates accessory saphenous tributary. (From Anson and McVay: Anat. Rec., 72: 399–404, 1938.)

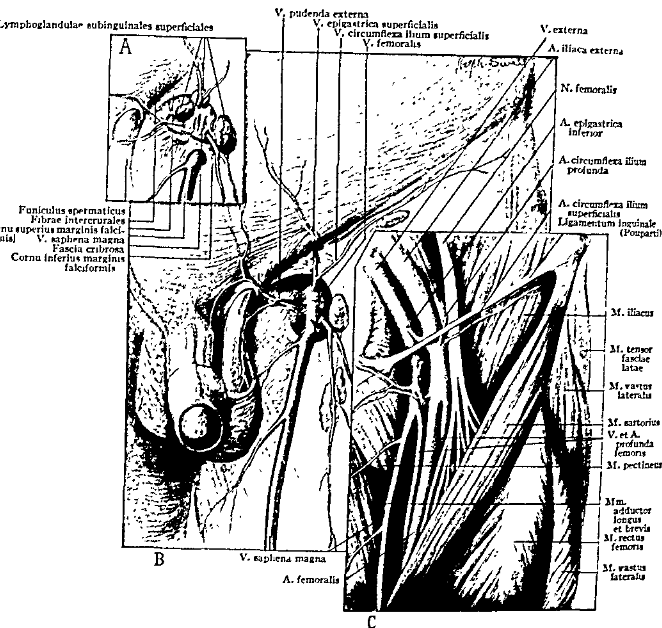


Fig. 903. LEVELS IN THE DISSECTION OF THE INGUINOFEMORAL REGION.

A, The relations of the fossa ovalis to the deep fascia of the thigh, the inguinal ligament and the superficial vessels. *B*, The fossa ovalis cleared of the lymphatic contents and the cribriform fascia. *C*, Exposure of the contents of the femoral trigone (of Scarpa) after all superficial structures and the deep fascia have been removed.

upper thigh and, after receiving numerous tributaries, pierces the cribriform fascia and enters the femoral vein. There sometimes is a venous swelling where the great saphenous vein enters the femoral vein; this may be mistaken for a femoral hernia, since the venous dilatation transmits an impulse on straining or coughing, and disappears in the recumbent position. In order to differentiate this condition from a femoral hernia, the patient lies down, and the swelling is reduced and held back by placing the finger on the proximal part of the fossa ovalis. When the patient stands, the swelling, if venous, gradually reappears as the great saphenous vein fills. With the limb in abduction and lateral rotation, the vein may be ligated through a transverse incision through the skin and subcutaneous tissue at the distal margin of the fossa ovalis.

The inguinal lymph nodes may be divided into a superficial and a deep group. The *superficial inguinal nodes*, with the saphenous vein and its tributaries, are situated within the deeper, or typically membranous, stratum of the superficial fascia of the thigh (Fig. 685); whether fibrous or fatty, the stratum is easily

separable from the subjacent fascia lata. The nodes vary in number from four to twenty-five, and their size is usually inversely proportional to the number present. They are commonly described in five groups (Fig. 685) receiving their afferent lymphatics from the skin of the anterior and lateral abdomen from about the level of the umbilicus downward; from the upper gluteal region; from the penis, scrotum, clitoris, vulva and portions of the external genitals outside of the hymen; from the perineum and cutaneous anal area; and from the thigh, leg and foot. Drainage from central areas may pass to both sides, and often there is abundant anastomosis across the midline.

As a group, the superficial inguinal lymph nodes are drained by means of efferent lymphatics chiefly into the external iliac group of glands, located along the course of the external iliac artery and vein (Fig. 922). However, they may also empty into the *deep inguinal glands* situated beneath the fascia lata on the femoral triangle (Fig. 921). These deep glands are smaller as a lot than the superficial, and form an almost continuous chain along the course of the femoral and deep femoral artery and vein. They may extend distally into the adductor canal, and proximally the chain is prolonged beneath the inguinal ligament to merge with the members of the external iliac set. While the deep inguinal glands are rather evenly distributed along the femoral vessels, a most constant and usually the largest member of the chain is the gland of Rosenmüller or Cloquet, situated in the femoral canal beneath the inguinal ligament and medial to the vein.

Structures between the Inguinal Ligament and the Iliopectineal Line. The space between the inguinal ligament and the iliopectineal line is divided into two compartments by a band of iliac fascia which extends from the inguinal ligament to the iliopectineal eminence at the outer side of the femoral artery (Figs. 903, 905, 907). The lateral space (*lacuna musculorum*) is somewhat oval; it is occupied by the iliopsoas muscle and the femoral (anterior crural) nerve. The medial smaller compartment (*lacuna vasorum*) is occupied by the femoral vessels and the femoral canal. The extreme lateral portion of the lacuna vasorum is occupied by the femoral artery and the lumbo-inguinal (crural) branch of the genitocrural nerve. The femoral vein lies more mesially; most mesial is the small, oval femoral ring, which serves as a communication between the abdominal cavity and the thigh (Figs. 903, 907).

Deep Fascia. The deep fascia in this region is a well defined structure (Fig. 903). Laterally, it encloses the tensor fasciae latae muscle; medially, it is attached to the inguinal ligament and the margin of the subpubic arch as far as the ischial tuberosity.

A gap of some size, the *fossa ovalis* (*saphenous opening*), lies in the deep fascia, distal to the medial extremity of the inguinal ligament (Figs. 685, 903). The middle of the opening lies 4 cm. distal and lateral to the pubic tubercle. The fossa is closed partially by the cribriform fascia, a loose and ill-defined portion of the fascia lata; which is pierced by numerous apertures. The fossa as an actual aperture does not exist until the *cribriform fascia* has been removed. The lateral border of the fossa is defined sharply into the falciform ligament, which overlies the venous compartment of the femoral sheath. The superior cornu of the ligament arches medially and proximally to the pubic tubercle, where it merges into the *lacunar ligament* (Figs. 905, 907). The well-marked inferior cornu is just distal to the junction of the saphenous and femoral veins. The medial margin of the fossa, formed by the deep fascia overlying the pectineus muscle, is defined poorly. When it is traced laterally, it disappears behind, then fuses with, the posterior layer of the femoral sheath.

Femoral Sheath. Within the lacuna vasorum, and for about 4 cm. distal to it, the femoral vessels are provided with a membranous investment known as the femoral sheath. This sheath is a sleevelike prolongation of the fascial envelopment of the abdomen which passes downward into the thigh behind the inguinal ligament. Lateral to the lacuna vasorum, mainly over the iliopsoas muscle, the transversalis and iliac fasciae are attached firmly to the inguinal ligament. Opposite the vessels, the fascial layers are carried into the thigh to form the femoral sheath. The anterior wall of the sheath is thin and continuous with the transversalis fascia lining the deep surface of the anterior abdominal wall; the posterior wall is constituted partly by the iliac fascia, which is prolonged downward over the iliopsoas muscle, and partly by the pubic portion of the fascia lata covering the pectineus muscle.

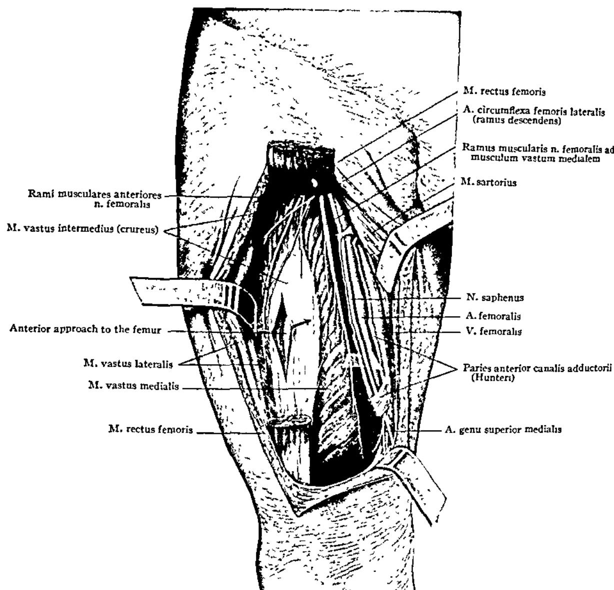


Fig. 904. DEEP STRUCTURES OF THE ANTERIOR REGION OF THE THIGH.
The drawing indicates the structures encountered in the anterior approach to the shaft of the femur.

The sheath extends downward as far as the origin of the profunda artery, where it fuses with the outer coats of the femoral vessels. Two septa from the femoral sheath divide the lacuna vasorum into arterial, venous and lymphatic compartments.

The medial compartment is the femoral canal, the entrance of which, the femoral (crural) ring, is an aperture bounded anteriorly by the inguinal ligament, posteriorly by the pectineus muscle and the subjacent pubic ramus, laterally by the femoral vein, and medially by the sharp lateral border of the lacunar ligament. The femoral ring (annulus femoralis) is occluded by a fascial septum (septum femorale), and is a weak area in the fascial envelope of the abdomen. It is important surgically because it allows the passage of a femoral hernia into the thigh (Figs. 910, 911).

Deep Musculature. The floor of the inguino-abdominal region is composed of the tensor fasciae latae, sartorius, iliopsoas, pectineus, and adductor longus muscles (Fig. 903, *C*). The tensor fasciae latae and sartorius muscles arise from a common origin at the anterior superior iliac spine. The iliopsoas and pectineus muscles are the substratum for the vasculoneural elements of the area; the adductor longus muscle, which forms the medial boundary of the region, is an element in the adductor region of the thigh (p. 980).

Femoral Trigone (of Scarpa). The femoral trigone is a triangular space lying im-

mediately distal to the inguinal ligament (Fig. 903, C). This ligament forms the base of the trigone (Figs. 903, 905, 907). The oblique lateral boundary is the medial margin of the sartorius muscle, and the medial boundary is the medial border of the adductor longus muscle. The roof consists of the fascia lata, which completely covers the space anteriorly. The floor is made up of two inclined planes, which form a well marked median groove at their junction. The laterally inclined plane consists of the iliopsoas muscle invested by a thin layer of fascia. The adductor longus and pectineus muscles, both of which are invested with fascia lata, form the medial plane. The most important contents of the prismatic space, included between the fascial roof and floor of the femoral trigone, are the femoral vessels and nerve and their large branches. These structures, the termination of the great saphenous vein, and the deep subinguinal lymph vessels and glands are embedded in a quantity of loose fatty tissue. The efferents from the popliteal gland end in this deep group which sends its efferent trunks to the external iliac lymph nodes. This space communicates with the abdomen through the lacuna vasorum.

Femoral Canal. The femoral canal is a narrow space bounded anteriorly by the cribriform fascia, posteriorly by the fascia lata over the pectineus muscle, and laterally by the femoral vein. The proximal aperture or inlet of the canal is the femoral ring, which is directed downward (Figs. 905, 907). The lower aperture, or outlet, is the fossa ovalis, which faces anteriorly. The canal is angular, with a decided forward curve which probably directs a femoral hernia forward and upward. The canal is occupied by the deep subinguinal lymph vessels, areolo-adipose tissue and one or two lymph nodes. It corresponds to the lymphatic compartment of the femoral sheath.

Surgical Relations of the Femoral (Crural) Ring. The *spermatic cord* lies superior and medial to the femoral ring. Between the cord and the femoral ring is the *pubic tubercle*, an important surgical landmark. If the hernial protrusion lies in front and to the inner side of this tubercle, it presumably emerges through the subcutaneous inguinal ring (inguinal hernia); if the herniating mass is inferior to, and to the outer side of, the tubercle, it almost certainly has made its way through the femoral canal (femoral hernia).

The obturator artery normally arises from the hypogastric artery (Fig. 906, *a*), but sometimes it is derived from the inferior (deep) epigastric artery. In the latter instance the obturator artery descends behind the pubis to the obturator foramen, but not always in

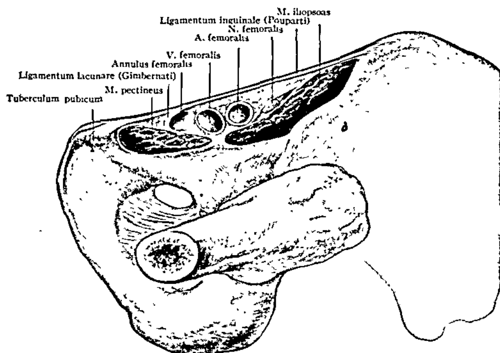


Fig. 905. CONTENTS OF THE FEMORAL ARCH VIEWED FROM THE THIGH.

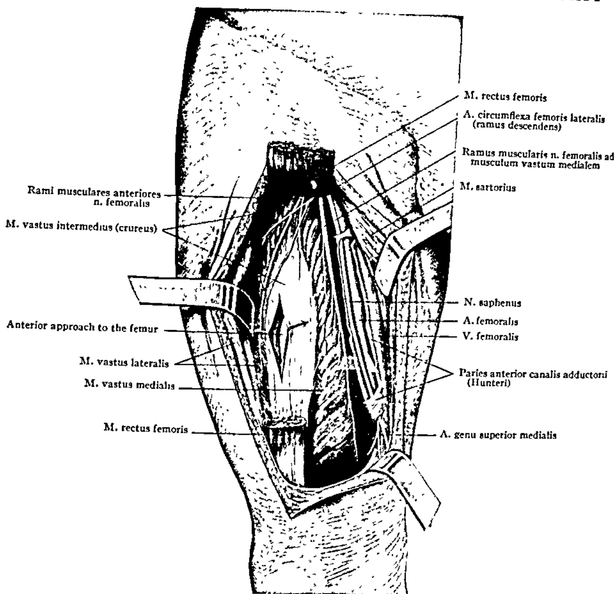


Fig. 904. DEEP STRUCTURES OF THE ANTERIOR REGION OF THE THIGH.
The drawing indicates the structures encountered in the anterior approach to the shaft of the femur.

The sheath extends downward as far as the origin of the profunda artery, where it fuses with the outer coats of the femoral vessels. Two septa from the femoral sheath divide the lacuna vasorum into arterial, venous and lymphatic compartments.

The medial compartment is the femoral canal, the entrance of which, the femoral (crural) ring, is an aperture bounded anteriorly by the inguinal ligament, posteriorly by the pectineus muscle and the subjacent pubic ramus, laterally by the femoral vein, and medially by the sharp lateral border of the lacunar ligament. The femoral ring (annulus femoralis) is occluded by a fascial septum (septum femorale), and is a weak area in the fascial envelope of the abdomen. It is important surgically because it allows the passage of a femoral hernia into the thigh (Figs. 910, 911).

Deep Musculature. The floor of the inguino-abdominal region is composed of the tensor fasciae latae, sartorius, iliopsoas, pectineus, and adductor longus muscles (Fig. 903, C). The tensor fasciae latae and sartorius muscles arise from a common origin at the anterior superior iliac spine. The iliopsoas and pectineus muscles are the substratum for the vasculoneural elements of the area; the adductor longus muscle, which forms the medial boundary of the region, is an element in the adductor region of the thigh (p. 980).

Femoral Trigone (of Scarpa). The femoral trigone is a triangular space lying im-

the same direction, for it may pass either medially or laterally to the femoral ring. Other origins have been observed in the senior author's laboratory, some of them representing striking departures from customary patterns (Fig. 906). When a femoral hernia coexists with an abnormal obturator artery which passes medial to the femoral ring, the artery lies in close relationship with the medial side of the neck of the sac and may be injured when the lacunar ligament is incised to relieve the constriction at the neck of the sac.

FEMORAL NERVE. The femoral nerve (L 2, 3, 4) enters the thigh behind the inguinal ligament, 1 cm. lateral to the femoral artery (Fig. 903, *C*). In the thigh it lies deep to the fascia lata in the groove between the psoas major and iliacus muscles. The saphenous nerve runs medially and distally toward the femoral artery at the apex of the femoral trigone and accompanies the artery down the adductor canal (of Hunter). Muscle branches supply the sartorius, pectineus and quadriceps muscles. The nerves to the vastus divisions of the quadriceps muscles give off articular branches to the knee joint, and the nerve to the rectus femoris muscle partially innervates the hip joint. Both the hip and knee joints also receive a nerve supply from the obturator nerve (p. 983). It is common for the pain of hip joint disease to be referred entirely to the knee.

FEMORAL ARTERY. The femoral artery, a direct continuation of the external iliac artery, enters the thigh behind the inguinal ligament midway between the anterior superior spine and the pubic tubercle (Fig. 903, *C*). It extends from this point to the upper and medial part of the popliteal space, which it enters through the tendinous ring in the adductor magnus muscle, a palmbreadth above the adductor tubercle. Between these two points the artery follows an almost straight course, gradually inclining from the anterior toward the posteromedial aspect of the limb (Fig. 904).

The femoral artery is comparatively superficial at its origin, but is deeply placed at its termination. The proximal half of the artery lies immediately behind the deep fascia, covering the femoral trigone. At a point about 4 cm. below the inguinal ligament the femoral artery gives off the large profunda branch. It is convenient to speak of the short portion of the femoral trunk above this branch as the

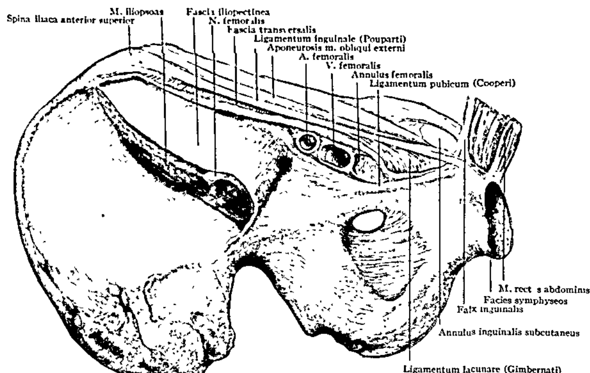


Fig. 907. CONTENTS OF THE LEFT FEMORAL ARCH VIEWED FROM WITHIN THE PELVIS.

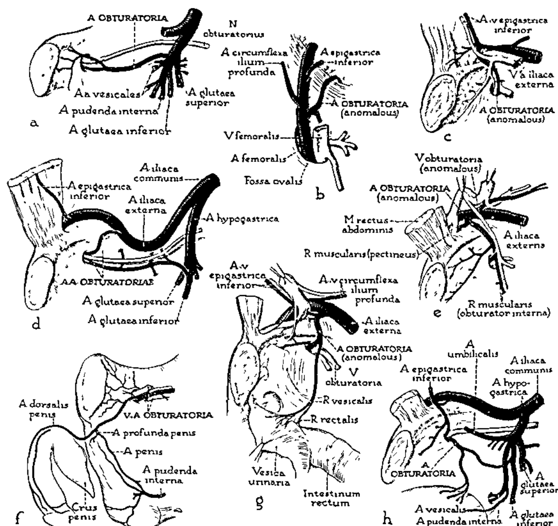


Fig. 906. OBTURATOR ARTERY; SELECTED EXAMPLES FROM AN EXAMINATION OF SPECIMENS FROM 640 BODY-HALVES.

a, Origin from the hypogastric division of the common iliac artery. *b*, Derivation from the femoral continuation of the external iliac artery. *c*, Origin from the external iliac artery near the inguinal ligament. *d*, Here one of a pair of obturator arteries is a branch of the superior gluteal; the other is derived from the external iliac. *e*, An origin from a common stem (from the external iliac) with a muscular ramus to the pectineus. *f*, An obturator artery which communicates with a penile branch of the internal pudendal. *g*, An example of obturator vessel which gives rise to the inferior epigastric, and to vesical and rectal branches. *h*, Obturator arteries arising from the inferior epigastric and the inferior gluteal branch of the hypogastric (the obturator of gluteal origin contributing to the blood supply of the urinary bladder). (Redrawn from Pick, Anson and Ashley: Am. J. Anat., 70: 317–43, 1942.)

the same direction, for it may pass either medially or laterally to the femoral ring. Other origins have been observed in the senior author's laboratory, some of them representing striking departures from customary patterns (Fig. 906). When a femoral hernia coexists with an abnormal obturator artery which passes medial to the femoral ring, the artery lies in close relationship with the medial side of the neck of the sac and may be injured when the lacunar ligament is incised to relieve the constriction at the neck of the sac.

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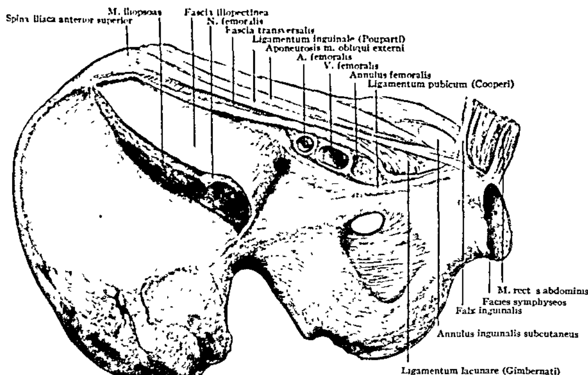


Fig. 907. CONTENTS OF THE LEFT FEMORAL ARCH VIEWED FROM WITHIN THE PELVIS.

common femoral artery. The remaining part is termed the superficial femoral artery.

BRANCHES OF THE FEMORAL ARTERY. Early in its course the femoral artery gives off SUPERFICIAL branches: the *superficial external pudendal*, the *superficial epigastric* and the *superficial circumflex iliac arteries* (*cf.* veins, Fig. 919).

The DEEP branches include the deep external pudendal, the profunda, the superior geniculate arteries, and the muscle branches. The *deep external pudendal artery* is derived from the medial aspect of the femoral artery and courses medially over the pectineus and adductor longus muscles. After piercing the fascia lata it is distributed to the scrotal tissues or to the labia majora.

The *profunda femoris artery* usually branches from the common femoral artery about 4 cm. below the inguinal ligament, and in its descent is first lateral, and then posterior, to the superficial femoral vessels. It soon passes beneath the adductor longus muscle, to which the superficial femoral artery remains superficial; the profunda artery runs in close proximity to the linea aspera of the femur. It descends toward the popliteal space, pierces the adductor magnus muscle close to the aperture for the femoral artery, and terminates as the fourth perforating artery.

The profunda artery has several important branches. The lateral circumflex artery sometimes arises from the common femoral artery, but usually is derived from the profunda close to its origin, and it passes laterally deep to the rectus femoris and sartorius muscles, where it is encountered in the anterior approach to the hip joint (p. 944). It divides into three terminal branches. The ascending branch runs upward and laterally beneath the rectus femoris and tensor fasciae latae muscles to the anterior part of the gluteal region. The transverse branch pierces the vastus lateralis muscle and winds around the posterior surface of the shaft of the femur. The descending branch descends within the vastus lateralis muscle to join the anastomosis around the knee joint.

The medial circumflex artery, which sometimes arises from the common femoral artery, generally originates from the profunda artery. It runs posteriorly and medially between the pectineus and psoas major muscles; for the remainder of its course it is contained within the upper part of the adductor region of the thigh (p. 980). The four perforating arteries arise from the profunda more distally and run to the posterior compartment of the thigh, where they form a regular chain of anastomoses extending from the gluteal region to the popliteal space. The first perforating artery contributes to the crucial anastomosis about the hip (p. 927), the second usually furnishes the chief nutrient artery to the femur, and the third and fourth, the terminations of the parent stem, anastomose freely with branches from the popliteal artery.

The *supreme geniculate* (*anastomotica magna*) *artery* arises from the superficial femoral artery in the lower part of the adductor canal (of Hunter). It divides into a superficial or saphenous branch and an articular branch. The latter descends on the femur and contributes to the anastomosis about the knee joint.

FEMORAL VEIN. The anatomy of this structure has become more important* because of the frequent ligation of the superficial femoral vein, mainly in the treatment of venous thrombosis in the leg or thigh. The femoral vein lies medial to the femoral artery at the inguinal ligament and from there down assumes a posterior position (Fig. 903, C). Occasionally it is found anteriorly or laterally (Fig. 902). Below the junction of the deep femoral it is called the *superficial femoral vein*, and above this point the *common femoral vein*.

The deep veins of the thigh join the femoral as several trunks. The deep femoral vein is almost always the most inferior of the venous channels (Fig. 908), terminating in the femoral vein at an average of 8 cm. *below* the inguinal ligament. At ascendingly high levels enter the lateral femoral circumflex, medial femoral circumflex and saphenous veins. Variations in the communications between the deep femoral and femoral veins are common (Figs. 908, 909).

The valves in the venous system of the legs are important factors in the return of blood from the dependent lower extremities to the heart. They are obstructions to the back flow of blood (Fig. 909), since they are set so that blood cannot flow downward and only from the superficial (saphenous) system to the deep (femoral) system. Contraction and expansion of the surrounding muscles on walking force blood upward out

* Edwards and Robuck: Applied Anatomy of the Femoral Vein and Its Tributaries. Surg., Gynec. & Obst., 85: 547-57, 1947.

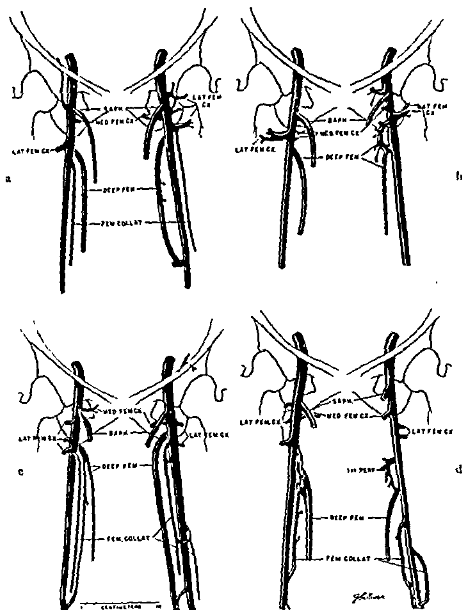


Fig. 908. VARIETIES OF COMMUNICATIONS BETWEEN THE DEEP FEMORAL AND FEMORAL VEINS.

a and *c*, The lower deep femoral has gross communications with the superficial femoral in 10 per cent of cadavers. *c*, *left*, The deep femoral is doubled. *b* and *d*, Varieties of communications of the upper deep femoral vein. (From Edwards and Robuck: Surg., Gynec. & Obst., 85: 547-57, 1947.)

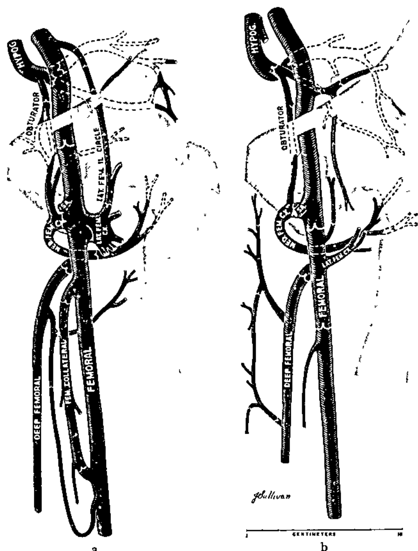


Fig. 909. VARIETIES OF VALVE ARRANGEMENT IN THE GROSS ANASTOMOTIC CHANNELS OF THE FEMORAL VEIN.

The action of surrounding muscles plays an important part in forcing blood upward out of the legs. *a*, The veins collateral to the lower femoral are valved centripetally. The veins extending from the upper femoral to the iliac veins are valved toward each parent trunk. *a* and *b*, The anastomosis from the medial femoral circumflex to the inferior gluteal is complete. The lateral femoro-iliac circle in *a* is complete, but in *b* is incomplete. (From Edwards and Robuck: Surg., Gynec. & Obst., 85: 547-57, 1947.)

of the legs. In the saphenous system these valves become inefficient and are destroyed when the dilatation and tortuosity of varicosity occurs. Inflammatory processes, such as phlebitis, also ruin these valves.

Ligation of the superficial femoral vein is often done for phlebothrombosis or thrombophlebitis without much disturbance of circulation. Interruption of the common femoral vein is a more formidable procedure (p. 968).

Surgical Considerations

FEMORAL HERNIA. In femoral hernia the abdominal contents push the parietal peritoneum, the extraperitoneal and femoral septum through the femoral ring into the femoral canal (Figs. 910 to 913). The protruding mass stretches the thin anterior wall of the femoral sheath and gains another covering. The sac, with its coverings, emerges through the fascia lata at the fossa ovalis and, following the course of least resistance, bends upward toward the inguinal ligament. It produces a palpable swelling at the medial part of the root of the thigh, below and to the lateral side of the pubic spine. There usually is a large amount of extraperitoneal fat about the sac, so that, even if the sac is small, the protruding mass appears

as an elongated, rounded, elastic swelling of considerable size (Fig. 910).

A femoral hernia comes to occupy the medial one of the three compartments within the femoral sheath. The space within the saccular protrusion is continuous with that of the peritoneal cavity; the parietal peritoneum, thus displaced, is covered by subserous and fascial coats. These layers press outward along the vascular lacuna, beneath the inguinal ligament, and into the "empty" compartment of the femoral sheath (*annulus femoralis*, Figs. 905, 907).

The descent of a femoral hernia is, therefore, at first almost directly downward into

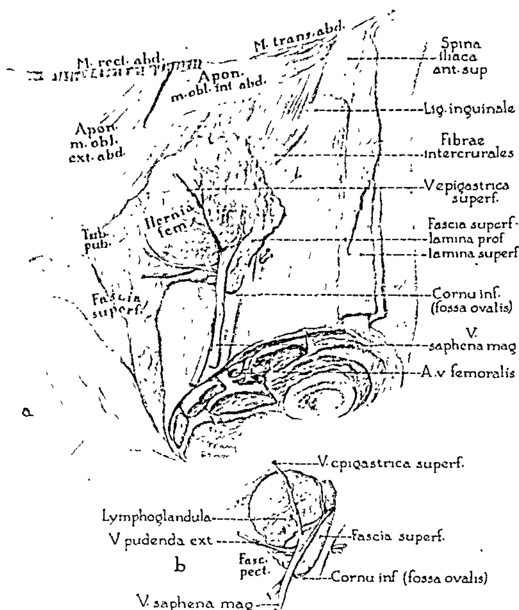


Fig. 910. FEMORAL HERNIA, IN RELATION TO THE EXTERNAL FASCIAL AND APONEUROTIC LAYERS OF THE INGUINAL AND PROXIMAL FEMORAL REGIONS.

a, The superficial fascia has been removed except in the territory of the hernia and in the pudendal area medial thereto. The aponeurosis of the external oblique muscle and the fascia lata are exposed, as is also the fossa ovalis in the latter layer (at the inferior horn of the falciform margin). The hernia produces a circular bulging in the overlying superficial fascia. The superficial veins form a basket-like support for the hernia. *b*, The hernial mass with related structures. (From Anson, Reimann and Swigart: Surg., Gynec. & Obst., 89: 752–63, 1949.)

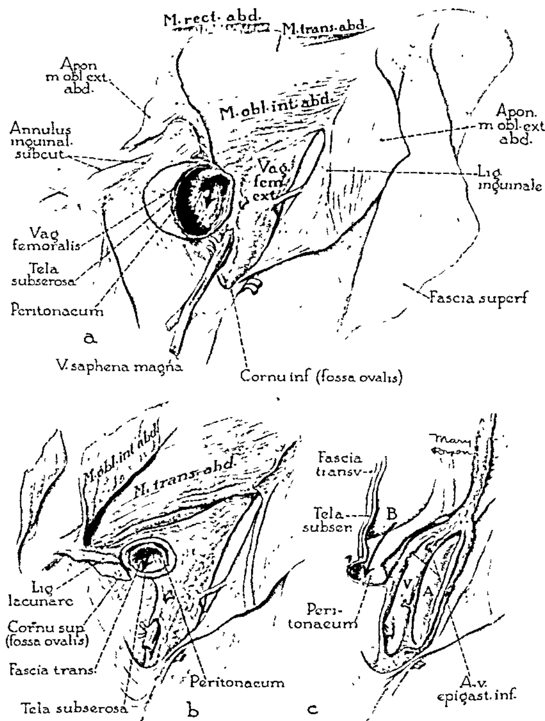


Fig. 911. ANATOMY OF THE REGION OF FEMORAL HERNIA.

a, The aponeurosis of the external oblique muscle has been reflected; with it the fascia lata has been turned aside after cutting vertically through the superior cornu of the falciform margin of the fossa ovalis. The lateral wall of the sac has been cut away. In this way the following features are demonstrated: the laminar nature of the hernial sac derived in part from the femoral sheath; the relation of the orifice (at the arrow) to the part of the sheath which invests the femoral vessels; the form and position of the sheath. The sac is composed of 3 layers: the fascia of transversus abdominis and iliopsoas muscles, the subserous connective tissue, and the peritoneum. The femoral sheath is made up of the outer and intermediate of these 3 layers.

b, The orifice of the hernial sac in relation to deep inguinal and femoral structures. The sac has been transected at its neck, and the internal oblique has been turned aside to expose the subjacent transversus abdominis. As the sac passes through the femoral canal, it is bounded medially by the lacunar ligament (here cut and turned downward), laterally by the portion of the femoral sheath which transmits the femoral vein, superiorly by the muscular layer of the transversus abdominis and liga-

the femoral fossa. Resistance to descent is offered, behind, by aponeurotic and ligamentous structures at the pubic pecten, and, in front, by the lacunar ligament. However, within the vascular lacuna the femoral vein and the investing sheath constitute a resilient lateral wall. Further progress caudalward brings the process into the lower portion of the femoral canal, where it impinges upon the overlying superior cornu of the fossa ovalis (Figs. 903, 911). After passing this point the herniating mass is suddenly relieved of ventral constriction; as a consequence, it presses against the integument in angulated course. While the neck of the process must remain small in size, the distal mass of the tumor may increase in bulk. Having attained the fossa ovalis, and carrying the bilaminar femoral sheath forward as an envelope, the hernia impinges upon the deep layer of the fatty pannicle of the thigh (Fig. 910).

In considering anterior hernial orifices together, the femoral canal with the ring represents an anatomic arrangement standing between inguinal and obturator canals in point of structural weakness. Tendency toward hernial protrusion through the inguinal wall is greatly increased by the presence of a congenital serous sac, and by exposure to the trauma and intra-abdominal tension of walls that are distensible. The femoral orifice is narrow, encircled in front by an aponeurotic arch, bounded by the lacunar ligament medially, and supported behind by a bony ridge. It is weakened only by the existence of potential space in the femoral ring and canal, and by resilience of the large blood vessels on its medial aspect. The obturator orifice, narrower still, is effectively bounded by an osseoligamentous rim. The obturator canal not only has peritoneal, preperitoneal and ligamentous tissues to support it internally, but also is well barricaded externally by the layered musculature of the thigh (Figs. 928, 929).

The *contents* of a femoral hernia usually is a tonguelike piece of omentum which seldom is more than partially reducible (Figs. 910, *b*; 912, *B*). This omental mass, by being converted into a plug of fibrofatty tissue, often loses its normal appearance. In addition, the sac may contain part or all of a coil of intestine. When part of the convex portion of a loop of intestine is nipped within the small space of a hernial ring, *Richter's hernia* results. A small area of bowel constricted in this manner may become gangrenous and lead to perforation as readily as a larger portion of strangulated bowel. When the bladder is part of the content of a femoral hernia, the herniating portion of the bladder wall usually is preceded through the ring by a mass of the prevesical fat. The viscus sometimes is wounded in high ligation of the neck of a hernial sac. A bladder diverticulum, normal in appearance, incarcerated or strangulated, may lie within the hernial sac.

In long-standing femoral hernias the strata of tissue about the sac are modified markedly. The layers may be attenuated by stretching, or may acquire such thickness from the accumulation of fat that it is impossible to recognize them individually.

Femoral hernia, in contrast to inguinal hernia, always is acquired, and occurs more frequently in females than in males, probably because of the greater proportional width of the pelvis, the consequent greater size of the femoral ring, and the tendency of pregnancy to produce an overstretched and atonic abdominal wall. If the iliopsoas muscle is not well developed, there is more room beneath the inguinal ligament than is necessary for the passage of the muscle and the femoral vessels, so that the potential space (femoral ring) medial to the vein is enlarged and is more capable of receiving a hernial sac.

The greater incidence of *incarceration* and *strangulation* in femoral hernia than in inguinal hernia is not surprising, considering the narrowness and unyielding quality of the femoral ring. In most instances it is the lacunar ligament which is responsible for the constriction, but the margin of an un-

mentous termination of the external oblique (inguinal ligament here cut and turned aside), and inferiorly by the superior ramus of the pubis (covered by the pectineus muscle and the pectineal fascia).

c, The compartments of the femoral sheath, their investments, contents and interrelationship. The hernial sac, in the medial one of the 3 compartments, has been opened in front, its constituent layers demonstrated by carrying the incisions vertically upward through the deep layers of the inguinal wall. Its space (traversed by arrow *B*) is continuous with that of the peritoneal cavity. The bilaminar division of the sheath, which houses the femoral vessels, has been opened to demonstrate the continuity of its strata with those of the abdomen. (From Anson, Reimann and Swigart: Surg., Gynec. & Obst., 89: 752-63, 1949.)

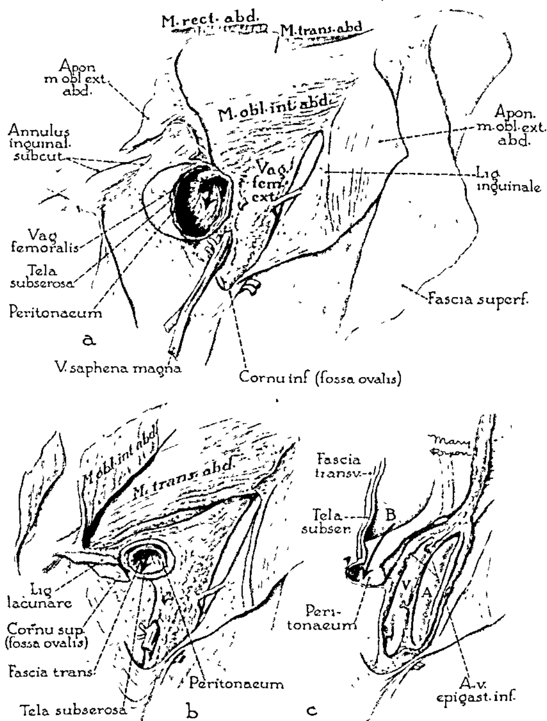


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because of the rigidity of the parts above the ligaments and the constant movements of the parts below them, none of these methods has proved altogether satisfactory. The usual course is to close the ring by sutures which draw the inguinal ligament to the pectineal fascia, or by a strong purse-string suture which puckers the fascia forming the femoral canal. The purse-string suture is passed through the inguinal ligament, the fascia lata, the falciform border of the fossa ovalis and the fascia over the pectineus muscle. It is difficult, if not impossible, to include in the suture Cooper's (superior pubic) ligament, the fibrous thickening on the pectineal line just proximal to the origin of the pectineus muscle. Care must be exercised not to injure the femoral vein.

Because of the tension on the stitches and the impossibility of securing a ligation of the sac flush with the abdominal peritoneum, the inferior approach is not nearly as satisfactory as the *inguinal approach*, which opens the inguinal canal as for the repair of inguinal hernia. After incising the transversalis fascia which forms the floor of the inguinal canal, the neck of the sac can be isolated in the extraperitoneal tissue proximal to the femoral ring. By pressure from below and traction from above, the sac sometimes can be drawn into the inguinal canal, where it can be incised and its neck ligated at its emergence from the abdominal cavity. The inguinal incision often must be continued into the thigh over the tumor mass in order to free the sac from the elements of the femoral canal; the sac can then be drawn upward into the inguinal canal. Both the inguinal canal and the femoral ring are closed by sutures which draw the inguinal falx (conjoined tendon) and the inguinal ligament down to Cooper's ligament on the iliopectineal line. In this operation the inferior (deep) epigastric

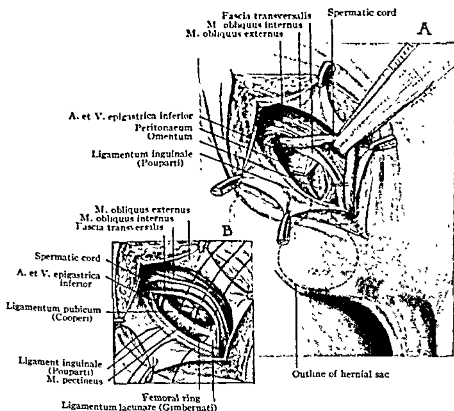


Fig. 913. INGUINAL APPROACH FOR REPAIR OF A FEMORAL HERNIA IN THE MALE.

A, The inguinal falx and the transversalis fascia are retracted upward. After exposing the peritoneum proximal to the femoral ring, the peritoneum is incised. The hernial contents are seen in the femoral canal. After withdrawal of the contents, the neck of the sac is ligated. If the sac and contents are adherent, an incision must be made over the hernial bulge in the thigh. *B*, The hernial contents and the sac have been drawn into the inguinal wound. The contents have been reduced and the sac has been ligated; the inguinal and femoral canals are closed by interrupted sutures, which pass through the inguinal falx, the inguinal ligament and the pubic ligament (of Cooper) on the iliopectineal line.

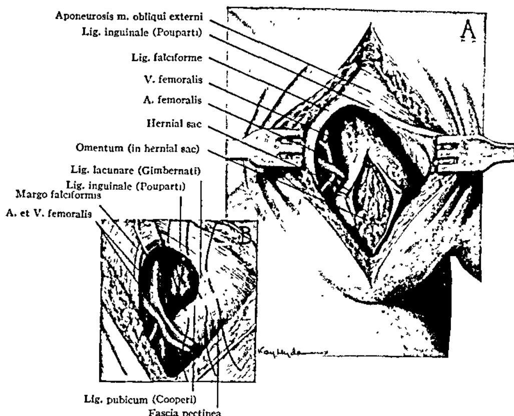


Fig. 912. SUBINGUINAL APPROACH FOR REPAIR OF A FEMORAL HERNIA IN THE FEMALE.

Vertical incision is made directly over the hernial protrusion. The sac is located in the midst of the superficial fat and the areolar tissue of the cribriform fascia, and is isolated by blunt dissection. Internally, the sharp edge of the lacunar (Gimbernat's) ligament may require division. Externally, the margin of the falciform may be sectioned to give exposure. After the contents of the sac have been reduced and the sac ligated and excised, the pectineal fascia is sutured to the inguinal and falciform ligaments.

duly rigid falciform ligament may be a factor. In attempting to reduce a femoral hernia, the thigh should be flexed and adducted slightly to relax the pectineus muscle, the fascia lata and the inguinal ligament. The herniating mass should be manipulated gently.

The *differential diagnosis* of femoral hernia from other lesions in the groin is decidedly more important than the distinction between the femoral and inguinal varieties of hernia. The most important and commonest of the lesions to be differentiated are enlarged inguinal glands, hydrocele of the cord or of the canal of Nuck, varix of the great saphenous veins at the saphenous opening, and psoas abscess which has gravitated downward beneath the inguinal ligament. The swelling of a psoas abscess is at the lateral side of the femoral sheath, because the pus usually enters the thigh through the lacuna musculorum. Examination generally reveals a fluctuant tumor in the iliac fossa; roentgenographic evidence of an enlarged psoas shadow or of vertebral caries confirms the diagnosis.

Operative Treatment of Femoral Hernia. The *subinguinal approach* to a femoral hernia is through an incision parallel with, and just distal to, the medial part of the inguinal ligament or through a vertical incision over the hernial protrusion (Figs. 912, 913). After division of the skin, superficial fascia and superficial vessels, blunt dissection reveals a mass of fat beneath the subcutaneous fatty areolar layer. The coverings of the hernia often cannot be differentiated. Further blunt dissection isolates the neck of the tumor at the femoral ring. The fatty tissue derived from the extraperitoneal tissue, and that distal to it, is incised step by step in the search for the hernial sac. Sometimes the herniating mass is a lipoma arising from the extraperitoneal fat. When the sac is found and its contents reduced, the sac is ligated and excised.

Many methods are used to close the femoral ring through the subinguinal incision, but,

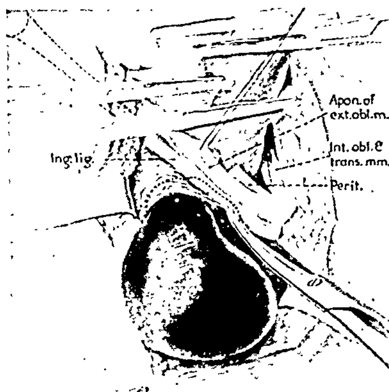


Fig. 914. REPAIR OF FEMORAL HERNIA WITH GANGRENOUS BOWEL.
Separation of the neck of the sac with retention of intact fibrous ring. Ultimate purpose is to carry out a block resection of the gangrenous sac and content, the loops of intestine to and from the hernia, and the intact fibrous ring as well. (From Dennis and Varco: Surgery, 22: 312–23, 1947.)

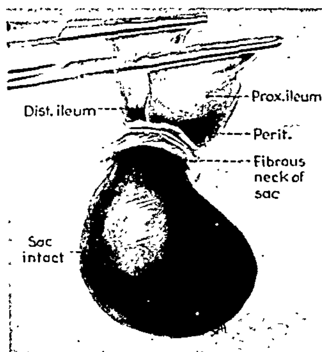


Fig. 915. REPAIR OF FEMORAL HERNIA WITH GANGRENOUS BOWEL (CONTINUED).
Aseptic resection of femoral hernia sac intact with fibrous ring of neck and contained necrotic material. (From Dennis and Varco: Surgery, 22: 312–23, 1947.)

artery and the external iliac vein must be retracted carefully.

The sac of a *strangulated femoral hernia* is difficult to recognize because of edema and congestion of the elements of the protruding mass. Each layer of the herniating mass must be incised separately through the subinguinal incision until the escape of discolored fluid from within the sac indicates the proximity of the bowel. Before the condition of the bowel at the constricted neck of the sac can be ascertained and reduction effected, the femoral ring must be enlarged. This is accomplished by introducing the knife, guided by the finger, along the medial aspect of the neck of the sac and dividing the free edge of the lacunar ligament until the opening is enlarged sufficiently to permit withdrawal of the bowel for examination. If division of the lacunar ligament does not afford sufficient exposure, the only alternative is section of the inguinal ligament, which does not interfere with successful repair of the abdominal wall, particularly if division is made close to the pubic spine and in a diagonal or staggered manner, and if the repair is performed accurately with nonabsorbable sutures. Incision of the lacunar ligament by the inguinal approach is a simple procedure that entails no risk of injuring an anomalous obturator artery.

If the segment of bowel in the sac is strangulated and frank gangrene with peritonitis present, a block resection of the gangrenous sac and contents can be done, thereby greatly reducing the mortality rate from such cases (Figs. 914, 915).

THE HENRY APPROACH TO FEMORAL HERNIA. The anterior, low midline extraperitoneal approach is considered by some surgeons to facilitate the repair of femoral hernias (Figs. 916, 917). Elective repair can be made in conjunction with other abdominal and pelvic operative procedures. An anomalous obturator artery, if present, is readily discernible and can be avoided or, if necessary, safely ligated. Cooper's ligament is accurately defined, and the obliteration of the femoral canal can be made with this ligament or pectineal fascia as snugly as desired without danger to the iliac vein, which is at all times under direct vision. The hernial sac and contents can be released by incising the lacunar and/or inguinal ligaments under direct vision. Abundant access to a wide area of parietal peritoneum is obtained so that complete inspection and other necessary definitive surgery can be performed with ease.

LIGATION OF THE FEMORAL VEIN. Active urgent treatment of deep, quiet thrombosis, phlebothrombosis, or the more inflammatory thrombophlebitis of the legs is indicated to prevent a thrombus from breaking loose, floating upward to and through the heart to the lungs and producing a fatal pulmonary embolus (p. 304). Prevention of this catastrophe is sought by two forms of therapy: (1) the use of heparin, Dicumarol and other anticoagulants, which prevents further thrombus formation and the seriousness of emboli; and (2) ligation of the femoral or iliac veins.

Thrombosis usually begins in the calf veins and extends upward for a considerable distance (Fig. 918), and emboli may break loose at any time. Among the fatal cases a third of the deaths occur from the second or third embolus; thus the first occurrence demands active treatment. If surgical treatment is decided upon, the real problem is the level at which the vein or veins shall be interrupted. If the symptoms are localized to the lower leg and involvement of the femoral vein is not expected, exploration and ligation of the femoral at the groin is carried out through an incision parallel to the groin and about 2 cm. below the inguinal ligament. If, as shown in Figure 918, *A*, no thrombus is seen in the vein, the *superficial femoral vein* is doubly ligated and divided. If a nonadherent, floating mass is encountered, the superficial femoral vein is opened, the soft clot is sucked out, and then the vein is doubly ligated and divided. There is little or no evidence of venous obstruction following ligation of the superficial femoral vein, and the incidence of postligation edema of the leg and foot is low.

If the thrombotic process is well established in the common femoral vein (above the entrance of the deep femoral), *ligation of the common femoral vein should not be done.* Disturbing edema of the leg and foot occurs too often after ligation of the common femoral vein, and collateral circulation from such a ligation is not nearly as good as that from ligation of the common iliac vein (Fig. 553, p. 564). Operative interruption of the latter is considered preferable.

These various femoral and iliac vein ligations are being done, *but not quite as fre-*

quently as three to four years ago. The use of heparin and Dicumarol is less disturbing to the patient and gives equally good results. It, too, is not without danger, since a severe hemorrhage occurs in at least 1 per cent of the cases in which it is used.

LIGATION OF THE FEMORAL ARTERY. It is the superficial position of the femoral artery in the femoral trigone which renders it liable to injury by lacerations or gunshot wounds at this level. The proximity of the femoral vein to the artery accounts for the readiness with which these vessels are wounded simultaneously. The result of this injury commonly is the establishment of an *arteriovenous fistula (aneurysm)*, of the aneurysmal varix or the varicose type. In the aneurysmal varix the injured vessels communicate directly; in the varicose aneurysm the communication is effected indirectly through the intermedium of a sac formed by the surrounding tissues.

Within the inguinofemoral region the femoral artery may require ligation immediately below the inguinal ligament (common femoral artery) or at the apex of the femoral trigone (superficial femoral artery).

Ligation of the common femoral artery is not difficult, because of the superficial position of the artery and the ease with which it can be separated from the femoral vein, inasmuch as each vessel occupies a separate compartment within the femoral sheath (Figs. 905, 907). The three small superficial branches of the common femoral artery (Fig. 685, p. 960) and the occasional origin of the circumflex vessels from this trunk make ligation of the external iliac artery (p. 564) the ligation of choice

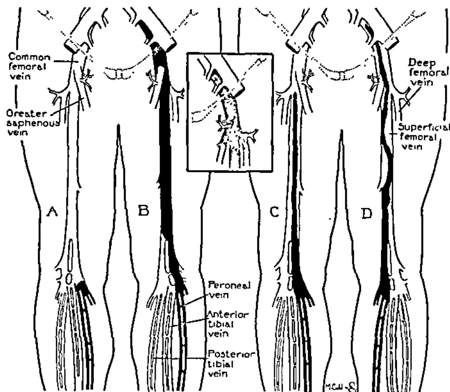


Fig. 918. DIAGRAMS SHOWING VARIOUS COURSES WHICH A DEEP, LOWER-LEG, QUIET THROMBOSIS (PHLEBOTHROMBOSIS) MAY FOLLOW.

As found clinically, the disease is shown starting in one of the 3 main venous systems of the calf. *A*, The process is represented as having failed to progress above the popliteal region. *B*, The thrombosis has progressed into the femoral vein, where it now fully obstructs the femoral and external iliac veins. This is the usual conception of femoro-iliac thrombosis, or *phlegmasia alba dolens*. No attempt is made to indicate the usual inflammatory reaction about the great vessels or the involvement of collateral channels. *C*, The thrombosis has formed a propagating floating mass, not adherent to or obstructing the femoral vein. Its proximal end might or might not be seen on opening the superficial femoral vein at the groin. At this stage a fatal pulmonary embolism is seriously threatened. *D*, The thrombosis has reached a fairly advanced stage, being adherent to, without obstructing, the femoral vein and having extended through the left external into the common iliac vein. At this stage, emboli of fair size may readily be detached. (From Homans: Surg., Gynec. & Obst., 79: 70–82, 1944.)

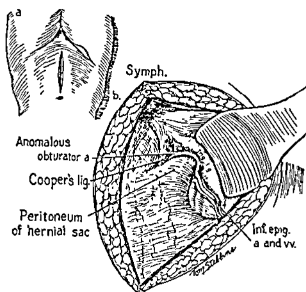


Fig. 916. THE HENRY APPROACH TO FEMORAL HERNIA.
a, Incision. *b*, Relationship of structures after retraction of right rectus muscle. (After Hull and Ganey: Ann. Surg., 137: 57–60, 1953.)

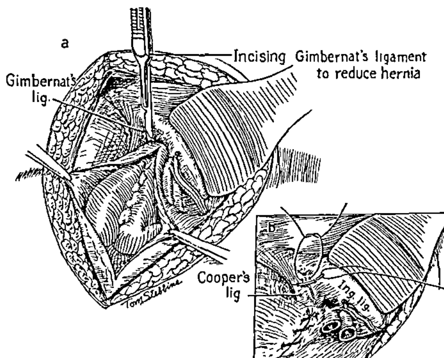


Fig. 917. THE HENRY APPROACH TO FEMORAL HERNIA (CONTINUED).
a, Obturator artery ligated. Hernia sac opened. Incising lacunar ligament to reduce hernia. *b*, Femoral canal obliterated by suturing the inguinal ligament to Cooper's ligament. Peritoneum closed. (After Hull and Ganey: Ann. Surg., 137: 57–60, 1953.)

technique also preserving the inguinal ligament and giving excellent exposure of the iliac vessels is that of Gray and Bailey* (Figs. 923 to 926).

As one might expect when lymphatic channels are removed, serum may collect under the skin flaps for long periods of time and in large quantities. Firm compression dressings aid in its elimination. Postoperative edema of the leg is also a frequent complication, but usually disappears after several months. When trying to cure cancer, such sequelae are annoying, but of minor importance.

* Gray and Bailey: Ann. Surg., 145: 873–87, 1957.

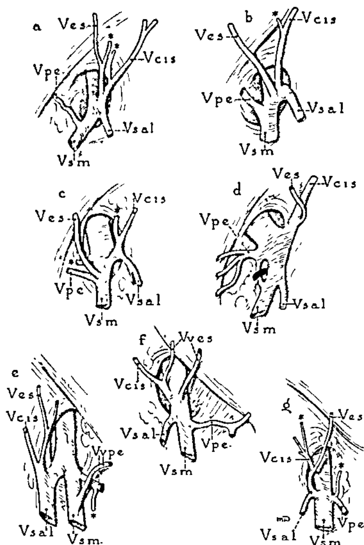


Fig. 919. TRIBUTARIES OF THE SAPHENOUS VEIN AT THE FOSSA OVALIS.

Variations in pattern selected from 500 specimens illustrate, when one is dealing with varicose veins, the thorough exploration of this region needed to interrupt completely the greater saphenous-venous system at its junction with the common femoral vein. All branches should be ligated and divided; the main saphenous trunk should be tied off at its junction with the common femoral vein, then ligated distally and divided between the ligatures. Some surgeons inject a sclerosing solution into the distal saphenous; others strip out this vein.

A common error is to place the main saphenous vein ligature too low, below a lateral accessory vein such as in *b* or *e*. These lateral veins usually anastomose with the main vein lower in the thigh, which forms a bypass around the point of ligation, and venous back-pressure is not stopped.

Abbreviations: *V.c.i.s*, vena circumflexa iliaca superficialis; *V.e.s.*, vena epigastrica superficialis; *V.p.e.*, vena pudenda externa; *V.s.a.l.*, vena saphena accessoria lateralis; *V.s.a m.*, vena saphena accessoria medialis; *V.s.m.*, vena saphena magna. (From Daseler, Anson, Reimann and Beaton: Surg, Gynec. & Obst., 82: 53–63, 1946.)

as a preliminary measure to disarticulation at the hip joint.

After ligation of the common femoral artery, collateral circulation is established through anastomosis between the superior and inferior gluteal branches from the hypogastric artery proximal to the ligature, and the two circumflex branches and the first perforating branch of the profunda distal to the ligature. Another collateral path is the anastomosis of the deep circumflex iliac artery (from the external iliac) with the superficial circumflex iliac artery and the ascending ramus of the lateral circumflex artery (from the femoral).

Ligation of the femoral artery at the apex of the femoral trigone is made through an incision over the course of the vessel. The sartorius muscle is identified and retracted laterally, and the artery is exposed just before it enters the adductor canal. The femoral artery is crossed at this level by the medial cutaneous nerve, to which the saphenous nerve is either anterior or lateral. Although the femoral vein lies to the medial side of the artery in the proximal part of the thigh, it occupies a position posterior to the artery at the apex of the femoral trigone. For this reason the sheath of the artery is opened at its anterolateral aspect. Collateral circulation is established by anastomoses around the knee joint, where branches from the profunda femoris artery communicate with the geniculate anastomosis on the proximal side of the ligature and with branches of the popliteal artery on the distal side.

Ligation of the femoral artery in the adductor canal (of Hunter) is described on page 987.

Ligation of the Saphenous Vein at the Fossa Ovalis. This procedure is usually done as part of the treatment of varicose veins of the greater or long saphenous system. As part of the disease, the valves in the saphenous vein are incompetent, and there is considerable back pressure from the long column of blood in the inferior vena cava. It has also been demonstrated that blood flow is often downward in well developed long saphenous varicosities. Return passage is then by way of the perforating veins to and upward through the femoral system. At the fossa ovalis a spill-back may occur which sets up a vicious, incompetent circle.

As a part of the effort to break this back pressure and downward flow of blood, the upper end of the long saphenous system is interrupted at its junction with the common femoral vein. This requires a good exposure of the fossa ovalis area through an oblique incision paralleling the inguinal ligament, and scrupulous care to divide the main saphenous trunk and all its tributaries. The surgeon must be aware of the many variations in the venous pattern of this area and deal with them properly to obtain the desired result (Fig. 919).

Additional therapy advised for varicose veins is the injection of a sclerosing solution into the varicose areas, ligation of incompetent connecting veins between the saphenous and femoral systems, and the stripping out of the varicose veins.

Abscess in the Root of the Thigh. *Superficial abscesses* usually originate in suppurating superficial subinguinal lymph nodes, the focus for which may be on some part of the limb or buttock, the anus or the external genitals.

Deep abscesses often are secondary, invading the thigh from an adjoining region. They manifest a decided tendency to gravitate beneath the deep fascia, since this dense structure is a powerful obstacle to the collection's becoming superficial. The pus, if not evacuated, usually descends along the lateral side of the femoral sheath; from this area it may be guided by the deep femoral vessels to the back of the thigh. The abscess may point at the medial aspect of the thigh. The path of pus from tuberculosis of the hip joint is alluded to in connection with that joint (p. 936).

Radical Ilio-inguinal Lymph Node Dissection. Radical groin dissections are indicated in the treatment of cutaneous malignancies encountered in the external genitals, lower extremities, umbilical and infra-umbilical abdominal wall, and gluteal, perineal and cutaneous anal regions. Pack believes that such operations are needed routinely in the treatment of melanomas of these areas, even in the absence of palpably enlarged nodes.

Several excellent techniques have been recommended for radical excision of the superficial and deep inguinal and external iliac lymph nodes.* The procedure of Daseler, Anson and Reimann (Figs. 920 to 922) is based on their anatomic dissections. Another

* Pack and Rekers: Am. J. Surg., 56: 545-65, 1942; Frieden: Surg., Gynec. & Obst., 89: 591-8, 1949; Daseler, Anson and Reimann: Surg., Gynec. & Obst., 87: 679-94, 1948.

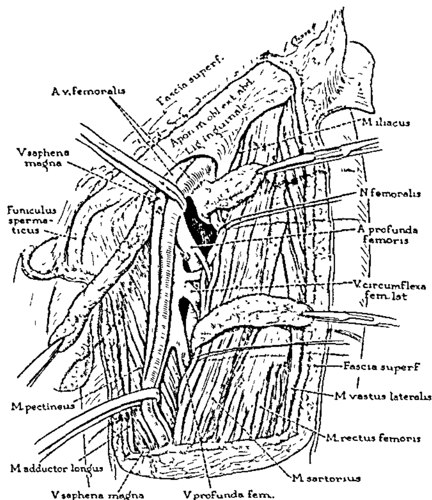


Fig. 921. RADICAL EXCISION OF DEEP INGUINAL LYMPH NODES.

Beginning at the apex of the femoral triangle, the fibrous layer of the femoral sheath with the contained gland-bearing adipose tissue is progressively removed, exposing the major vessels and nerves shown. Minor blood vessels to the pectineus, iliopsoas, quadratus femoris and adductor muscles are usually ligated to facilitate the dissection. The excision is then continued upward to remove the external iliac glands (Fig. 922). The external oblique aponeurosis is cut in the direction of its fibers from the subcutaneous inguinal ring to a point 1 to 2 inches lateral to the abdominal inguinal ring. The spermatic cord (or round ligament) and the inguinal canal are thoroughly cleaned of investing connective tissue. The transversalis fascia is freed from its attachment to the inguinal ligament and the subjacent iliopsoas and pectineus muscles. (From Daseler, Anson and Reimann: Surg., Gynec. & Obst., 87: 679–94, 1948.)

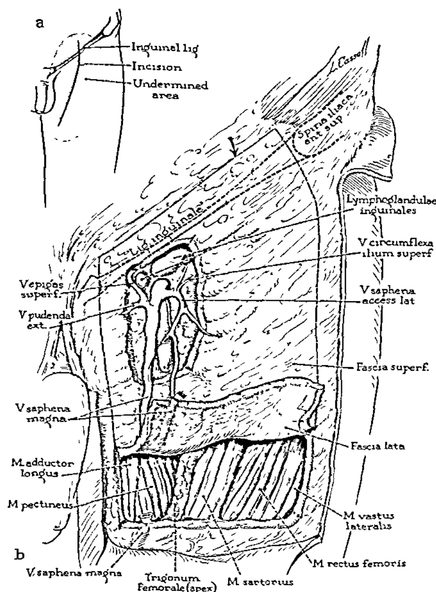


Fig. 920. RADICAL EXCISION OF SUPERFICIAL INGUINAL LYMPH NODES.

a, Direction and extent of surgical incision. Undermined skin flaps should not contain more than 3 to 5 cm. of fat. *b*, The structures contained in the quadrilateral "block" of tissue to be excised, with center showing particularly the veins and lymph nodes about the fossa ovalis. Beginning below, the great saphenous vein is ligated, and the superficial fascia and fascia lata are elevated, thus removing the saphenous vessels and all superficial inguinal lymph nodes and exposing the underlying musculature of the thigh. (From Daseler, Anson and Reimann: Surg., Gynec. & Obst., 87: 679–94, 1948.)

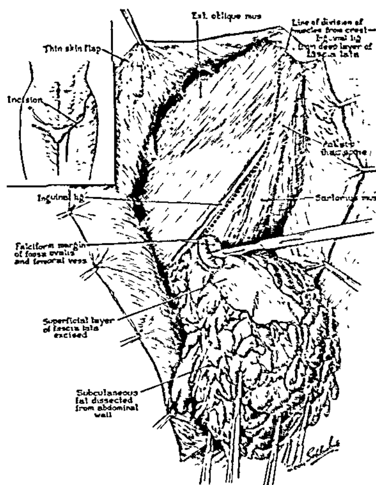


Fig. 923. RADICAL ILIO-INGUINAL LYMPH NODE DISSECTION.

Inset shows incision allowing adequate exposure of the area. Skin flaps with 2 to 3 mm. of fat attached are widely dissected. The superficial fat and the vessels of the lower abdominal wall are dissected from the external oblique muscle and fascia down to the inguinal ligament and retracted onto the thigh. The fascia lata is removed, beginning at the lateral border of the sartorius muscle, and dissected medially to the femoral vein and inferiorly to the lower angle of the femoral triangle, care being taken to avoid injuring the lateral femoral cutaneous and femoral nerves. The inguinal ligament is detached from the anterior superior spine, the incision being carried upward, leaving 1 cm of muscle attached to the iliac crest to facilitate closure. The entire lower abdominal wall along with the peritoneum and its contents can then be reflected medially so that there is an unobstructed approach to the entire retroperitoneal space. (From Gray and Bailey: Ann. Surg., 145: 873–87, 1957.)

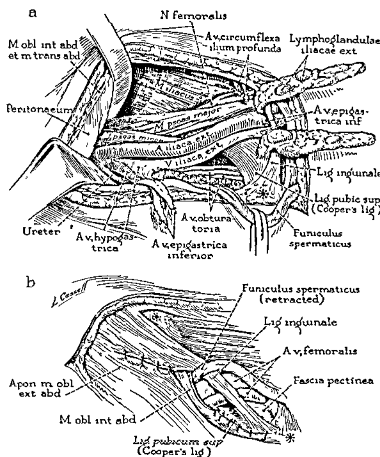


Fig. 922. RADICAL EXCISION OF EXTERNAL ILIAC LYMPH NODES (CONTINUED).

The peritoneum is raised from the lateral wall and floor of the pelvis by blunt dissection and retracted cephalad, to expose the common iliac vessels well above their bifurcation and close to the crossing of the ureter. The obturator nerve and vessels in the lateral pelvic wall are also exposed. To facilitate this exposure, the inferior epigastric and deep circumflex iliac branches of the external iliac artery and vein are divided. The spermatic cord is retracted medially, and beginning near the aorta the investing sheaths with surrounding gland-bearing fibro-adipose tissue are dissected way from the common and external iliac and hypogastric vessels down to the inguinal ligament. The obturator nerve and vessels are similarly freed of surrounding tissue.

In closing this area, *b*, the hernia techniques devised by McVay and Anson have been successfully used (Figs. 376 to 378). For the thigh, the skin flaps are approximated. A compressive dressing should be applied. (From Daseler, Anson and Reimann: Surg., Gynec. & Obst., 87: 679–94, 1948.)

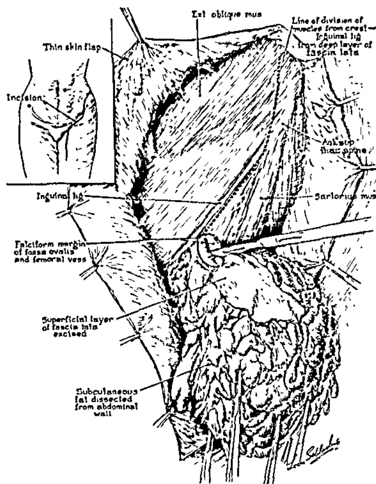


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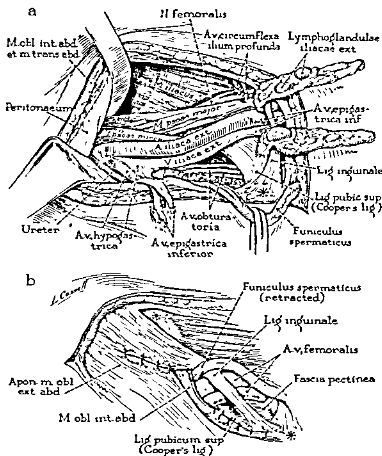


Fig. 922. RADICAL EXCISION OF EXTERNAL ILIAC LYMPH NODES (CONTINUED).

The peritoneum is raised from the lateral wall and floor of the pelvis by blunt dissection and retracted cephalad, to expose the common iliac vessels well above their bifurcation and close to the crossing of the ureter. The obturator nerve and vessels in the lateral pelvic wall are also exposed. To facilitate this exposure, the inferior epigastric and deep circumflex iliac branches of the external iliac artery and vein are divided. The spermatic cord is retracted medially, and beginning near the aorta the investing sheaths with surrounding gland-bearing fibro-adipose tissue are dissected way from the common and external iliac and hypogastric vessels down to the inguinal ligament. The obturator nerve and vessels are similarly freed of surrounding tissue.

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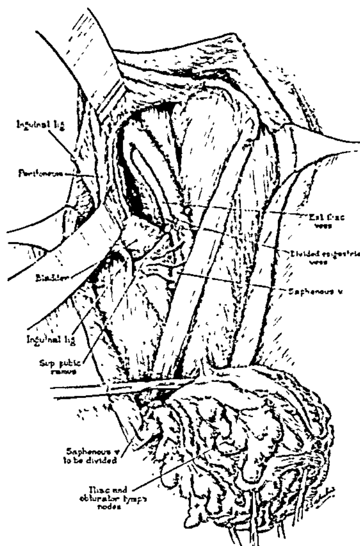


Fig. 925. RADICAL ILIO-INGUINAL LYMPH NODE DISSECTION (CONTINUED).

The great saphenous vein is ligated at its point of proximity to the lower angle of Hunter's (adductor) canal, and the dissection is continued upward, exposing the structure shown to the saphenofemoral junction, where the saphenous is ligated. Meeting the dissection from above, all glands and surrounding fibro-adipose tissue are then removed en bloc. Detaching the sartorius muscle and transplanting it over the femoral vessels to protect them has not been necessary. (From Gray and Bailey: Ann. Surg., 145: 873-87, 1957.)

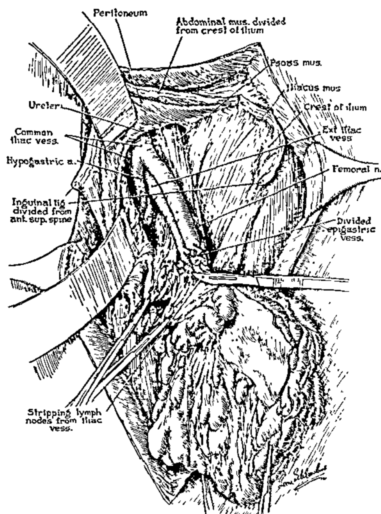


Fig. 924. RADICAL ILIO-INGUINAL LYMPH NODE DISSECTION (CONTINUED).

Excellent exposure of left lower retroperitoneal space up to the common iliac vessels. By starting above and using sharp dissection, the lymph node-bearing tissue is removed from the common iliac, internal iliac and external iliac vessels. The obturator nodes are removed as a separate group with this dissection. (From Gray and Bailey: Ann. Surg., 145:873-87, 1957.)

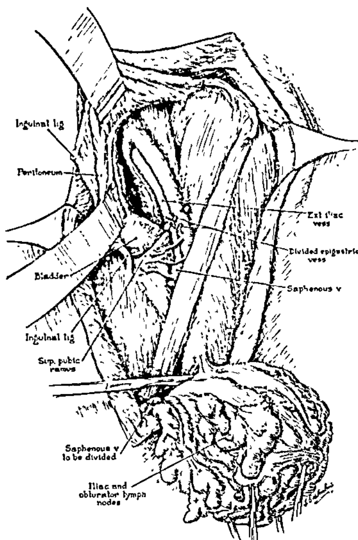


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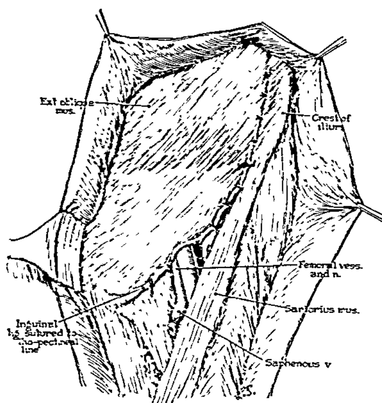


Fig. 926. RADICAL ILIO-INGUINAL LYMPH NODE DISSECTION (CONCLUDED).

The wound is closed by resuturing the transversalis and internal oblique muscles and the external oblique fascia as one layer to the iliac crest. No attempt is made to resuture the inguinal ligament to the anterior superior spine; instead, it is sutured to the medial border of the sartorius, also to the iliacus and pectineus muscles. It is tacked snugly laterally and medially; around the femoral artery and vein care is taken not to compromise the lumen of these vessels. The subcutaneous tissues are reapproximated with interrupted sutures, as are the skin edges. A drain is brought out through the subinguinal area and another at the lower end of the incision. A large compressive dressing is applied. Bilateral inguinal dissections can be carried out simultaneously without fear of serious postoperative lymphedema or herniation. (From Gray and Bailey: Ann. Surg., 145: 873–87, 1957.)

Adductor or Obturator Region

Definition and Boundaries. The adductor region is a wedge of muscles interposed between the extensor group of thigh muscles in front and the flexor muscles behind. The adductor muscles arise from the margins of the obturator foramen and from the obturator membrane (Figs. 927 to 929). Within this region is the obturator canal, which is a potential pathway for an obturator hernia. The adductor region is limited medially by the pubic arch, the perineum and the gracilis muscle; laterally, by the hip joint and shaft of the femur; and above, by the horizontal ramus of the pubis. Its lower boundary is the inferior insertion of the adductor magnus muscle into the adductor tubercle of the femur.

Adductor Musculature. From a restricted area on the pubis the collective adductor muscles (N. obturator, L 2, 3, 4) and the pectineus and gracilis muscles spread fanwise to the linea aspera along almost the entire length of the femur.

The *pectineus muscle* (N. femoral, L 2, 3) arises from the superior ramus of the pubis, passes distally and laterally, and inserts into the posterior aspect of the proximal part of the femoral shaft just behind and below the lesser trochanter. It also is a constituent muscle of the inguinofemoral region and is an adductor and flexor of the thigh.

The *gracilis muscle*, thin and straplike, extends from the margin of the pubic arch along the medial side of the thigh. Before inserting into the proximal part of the tibia, it runs behind the medial epicondyle of the femur, and acts more powerfully as a flexor of the knee than as an adductor of the thigh. When the hamstring muscles are paralyzed, flexion of the leg may be carried out by the gracilis and sartorius muscles.

The *adductor longus muscle* forms part of

the floor of the inguinofemoral region (p. 956) and of the adductor canal (p. 987); therefore it is a support for a considerable extent of the femoral vessels. The adductor longus is the most anterior of the three adductor muscles, and is on the same plane as the pectineus. It inserts into the linea aspera. The *adductor brevis muscle* lies deep to the adductor longus, arises from the inferior ramus of the pubis, and inserts into the back of the femur. Its superior margin lies against the obturator externus muscle. The *adductor magnus muscle*, the largest and most posterior of the three adductors, forms a broad triangular floor for the support of the other muscles of the adductor group. It arises from the pubic arch and the ischial tuberosity. Its upper fibers run horizontally to the back of the femur, and the lower fibers run downward almost vertically to insert into the linea aspera and the adductor tubercle. The anterior surface of the upper part of the adductor magnus is covered by the adductor brevis. More inferiorly, the adductor magnus is overlaid by the adductor longus; inferior to the adductor longus, it forms the floor of the adductor canal. The adductor magnus, in its inferior part, presents a tendinous hiatus for transmission of the femoral vessels to the popliteal fossa. Along the insertion of the muscle into the linea aspera are osteo-aponeurotic passages for the perforating branches of the profunda artery. Injuries to the adductor muscles, such as are sustained readily by cavalrymen, may cause hemorrhages which undergo calcification (myositis ossificans).

The *obturator externus muscle* (posterior

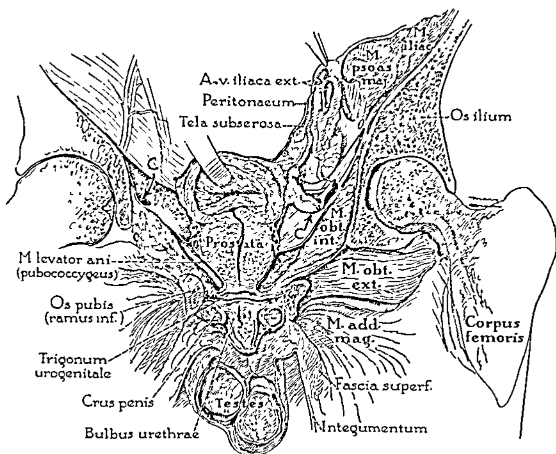


Fig. 927. ANATOMY OF THE REGION OF OBTURATOR HERNIA; CORONAL SECTION OF THE PELVIS OF AN ADULT MALE, VIEWED FROM BEHIND.

The peritoneum and preperitoneal tissue have been elevated on the right side to demonstrate a hernia-like lobule of the preperitoneal layer (at arrow C) and the related obturator artery, vein and nerve. These layers have been removed on the left (empty obturator canal indicated by arrow). The heavy preperitoneal layer is chiefly fatty; it is relatively thin in the greater pelvis, but thick in the lesser pelvis where it passes between the external iliac vessels and the urinary bladder. (Anson, McCormack and Cleveland: Surg., Gynec. & Obst., 90: 31-8, 1950.)

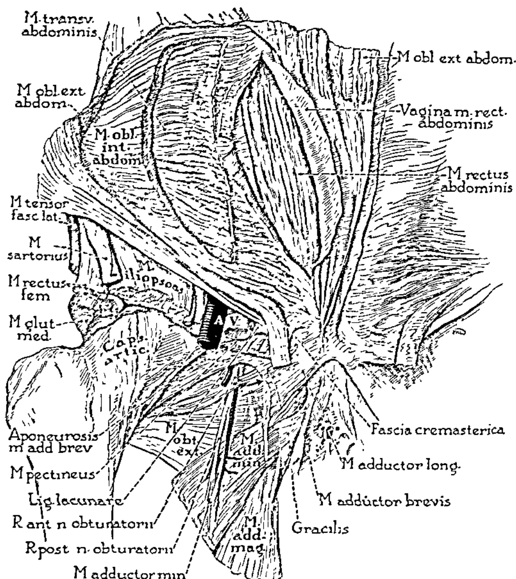


Fig. 928. ANATOMY OF THE REGION OF OBTURATOR HERNIA, VIEWED FROM THE FRONT.

The external oblique has been turned aside, and a window cut in the internal oblique to reveal the subjacent transverse abdominal muscle. The rectus sheath has been opened by a longitudinal incision. In the thigh the following muscles have been cut: tensor fasciae latae, sartorius, rectus femoris (both heads), iliopsoas, pectineus, adductor longus, adductor brevis, adductor magnus and obturator externus. The adductor brevis muscle arises not only from the inferior pubic ramus, but also from the superior ramus (lateral to the arrow) and from the capsular tissue of the hip joint. The anterior division of the obturator nerve has been cut near the point of emergence from the foramen; the posterior division remains intact. (Anson, McCormack & Cleveland: Surg., Gynec. & Obst., 90: 31–8, 1950.)

branch of N. obturator, L 3, 4) arises from the mesial margin of the obturator foramen and from the lateral surface of the obturator membrane; its tendon passes, almost horizontally, laterally to an insertion into the trochanteric fossa of the femur. It is a powerful lateral rotator of the thigh.

OBTURATOR CANAL. There is a gap at the superolateral part of the obturator foramen. This opening enters a short oblique tunnel, the obturator canal, which is directed forward and medially from the pelvis and relates the pelvis with the adductor region along the course of the obturator vessels and nerves emerging through it. Its length is from 1 to 2 cm., and its breadth is about 1 cm. The canal is bounded superiorly by the obturator groove of the pubic bone and inferiorly by the obturator membrane and the two obturator muscles. The internal or *pelvic orifice* of the canal is overlaid by the parietal pelvic fascia and the pelvic extraperitoneal space. The external or *super-*

ficial orifice is related to the deep aspect of the pectineus muscle (Fig. 929) and is slightly medial to the femoral vein.

OBTURATOR ARTERY AND NERVE. The *obturator artery* usually arises from the hypogastric artery. It occupies the lateral part of the obturator canal and accompanies the obturator nerve (Fig. 928).

The *obturator nerve* (L 2, 3, 4), a branch of the lumbar plexus, runs through the psoas muscle over the sacroiliac joint and along the lateral wall of the pelvis, where it enters the obturator canal. Within the canal it divides into two branches (Fig. 928). The anterior branch passes over the upper border of the obturator externus muscle and descends behind the pectineus and adductor longus and brevis muscles. The posterior branch, after piercing the upper margin of the obturator externus muscle, which it supplies, descends between the adductor brevis and adductor magnus muscles. It supplies the adductor magnus and gives off a small branch to the knee joint. Both the artery and the nerve run in a bed of areolo-adipose tissue which connects the extraperitoneal tissue of the pelvis with the corresponding tissue in the upper and inner thigh. This continuity affords a reciprocal path of infection between the regions. Along this path the pelvic peritoneum may be prolonged and may furnish the sac for an obturator hernia.

Surgical Considerations

OBTURATOR HERNIA. A hernia of pelvic contents may traverse the obturator canal with the obturator vessels and nerve and present at the upper and medial part of the thigh (Figs. 927 to 929); its occurrence is extremely rare, but it is more common in females than in males. When conditions are favorable for the formation of a hernia, forcible straining causes a loop of bowel, a diverticulum from the bladder, a portion of omentum, or even an ovary or a tube to become engaged within the narrow internal orifice of the obturator canal.

An obturator hernia usually is small. Since the outer orifice of the canal is located deep to the pectineus and adductor longus muscles, little protrusion is noted externally, and

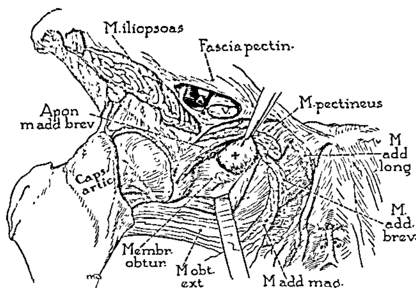


Fig. 929. OBTURATOR REGION; DISSECTION CARRIED TO THE LEVEL OF THE OBTURATOR MEMBRANE AND OBTURATOR CANAL.

The capsule of the hip joint has been partly removed to show the relation between the obturator structures and the head of the femur. The pectineus and adductor longus have been cut close to their origins. The adductor brevis muscle and its aponeurosis have been retracted cranialward with the underlying hernial protrusion (at +). The obturator externus has been freed from the obturator membrane, and retracted caudalward. It is thereby demonstrated that the origin of the adductor brevis extends lateralward to fuse with the capsule of the hip joint, and that, in being thus prolonged, it normally covers the external aperture of the obturator canal (here occupied by a hernia adiposa). (Anson, McCormack and Cleveland: Surg., Gynec. & Obst., 90: 31-8, 1950.)

the presence of the hernia may be unsuspected. This condition should be considered a possible cause of acute intestinal obstruction. Certain diagnostic signs are present in some cases. The protrusion causes pressure on the obturator nerve and tenderness in the adductor muscles, with pain referred to the cutaneous distribution of the obturator nerve on the mesial side of the thigh. The hernia, which usually is strangulated, lies behind the pectineus muscle on the obturator externus muscle and produces a slight fullness in the upper and medial part of the thigh. The thigh is flexed to relieve tension on the pectineus muscle; efforts at extension or adduction cause severe pain, since both movements tend to squeeze the hernia against the external obturator muscle. Mesial rotation of the thigh aggravates the pain by stretching the obturator externus muscle. Rectal or vaginal examination confirms the diagnosis. Heavy muscles, membranes and ligaments guard the obturator canal (Figs. 928, 929). The orifices are small; the canal transmits lesser nerves and vessels.

In the femoral region, on the other hand, the "space" within the sheath is filled in approximately the lateral two thirds by vessels, but is empty (save for areolar tissue and lymphatic elements) in its medial third (p. 953). The peritoneum rests almost directly against the internal orifice (femoral ring) of the canal; only a thin stratum of retroperitoneal tissue intervenes. The latter relationship makes for weakness against herniation. However, some strength is lent by other factors, namely, a strong ligament (lacunar) medially, a taut ligament (inguinal) superiorly, a bone (pubis) inferiorly, and vessels (femoral) laterally.

The inguinal is even less resistant than the femoral (p. 962). In descent of an indirect hernia a funicular "space" is merely made more capacious, displacement of investing coats being possible on three of the four aspects. In succession the abdominal orifice is dilated, the inguinal opening distended, and the space bounded by the crura at the subcutaneous "ring" is widened. Once the peritoneal diverticulum is occupied, further extension is not hindered by presence of strongly resisting structures. As the hernial mass advances, it dilates, in succession, a serous layer (the processus vaginalis), a thin subserous stratum, and three layers which are chiefly fascial. Of the three hernial areas, the inguinal is least well guarded by musculature and skeletal structure; the obturator is most effectually barricaded. Upon the basis of anatomic structure it would be expected that herniation would occur in the following order of frequency: inguinal, femoral and obturator—an order actually obtaining, as evidenced by laboratory and clinical records.

The vertical incision for *obturator herniotomy* overlies the interval between the pectineus and adductor longus muscles. The pectineus muscle is drawn laterally and may require partial division close to its pubic attachment. The body of the adductor brevis muscle is retracted distally and medially, and some of the fibers may require division. The relation of the vessels to the sac is variable, and a free dissection is necessary for adequate exposure of the parts adjacent to the neck of the sac.

Intrapelvic Extraperitoneal Resection of the Obturator Nerve. In severe spastic paraplegia or hemiplegia, overactivity of the adductor muscles of the thigh is undoubtedly the greatest obstacle to useful functioning of the lower extremities. A *scissors gait* or position of the legs not only impedes progression, but also contributes to the development of deformities of the knee, ankle and foot. Conservative correction of the disabling overactivity of the adductor muscle groups by active and passive stretching with or without retention in plaster, or by tenotomy or myotomy of the adductor groups, has given rather disappointing results.

The conversion of the rigid spastic state into that of a flaccid paralysis by neurectomy has been found to be most beneficial. The branches of the obturator nerve were first resected in the upper thigh, but in recent years an intrapelvic extraperitoneal approach has been adopted (Fig. 930). Its advantages are as follows: (1) The main trunk of the obturator nerve is exposed satisfactorily with a minimum of trauma. (2) The incision is in a location little exposed to contamination, closes well, and is inconspicuous. (3) Retention of the legs in abduction by braces or casts is not necessary. (4) The active use of other muscle groups of the leg is not even temporarily impeded. (5) A satisfactory correction of the adductor spasm is obtained.

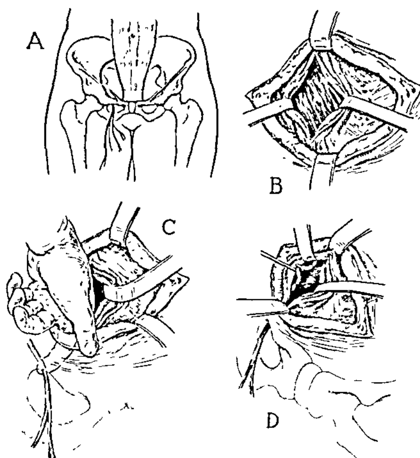


Fig. 930. INTRAPELVIC EXTRAPERITONEAL RESECTION OF THE OBTURATOR NERVE.

A, Course of obturator nerve. *B*, Transverse skin incision made following the transverse crease just above the pelvis; a vertical split in midrectus sheath; the lateral edge of rectus muscle freed. *C*, Rectus muscle retracted medially and transversalis fascia and peritoneum exposed. The index finger is used as a blunt dissector, following the posterior surface of the muscle to its insertion on the body and horizontal ramus of the pubis and entering the space of Retzius. The finger is then directed laterally and more deeply along the horizontal ramus of the pubis, displacing the bladder and the lateral folds of the peritoneum posteriorly until the upper portion of the obturator fascia overlying the obturator internus muscle is palpated. The obturator nerve is then felt as a small cordlike structure on the inner pelvic wall just below the lower margin of the horizontal ramus of the pubic bone. *D*, With medial retraction of the peritoneum and bladder, the fatty areolar tissue overlying the obturator nerve is opened and the nerve exposed. It is then hooked up and a small segment excised. Thorough hemostasis is obtained.

Resection of the opposite side is done in the same manner. (From Chandler and Seidler: Surg., Gynec. & Obst., 69:100–102, 1939.)

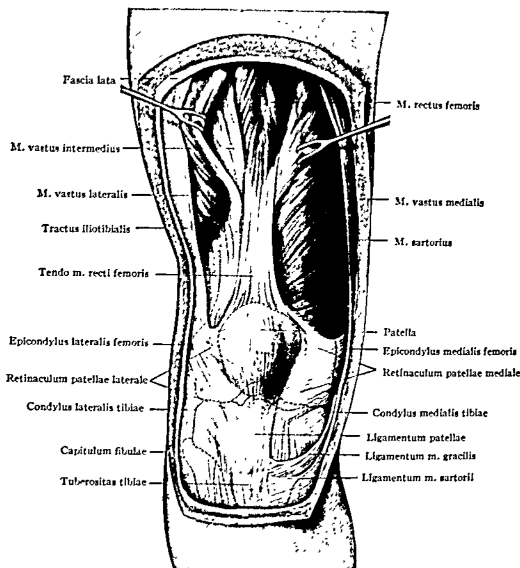


Fig. 931. SUPERFICIAL MUSCULO-APONEUROTIC STRUCTURES OF THE ANTERIOR REGION OF THE THIGH AND KNEE.

Anterior or Extensor Region of the Thigh; Shaft of the Femur

MUSCULATURE. The *tensor fasciae latae muscle* is described on page 926. The *sartorius muscle* (N. femoral, L 3, 4) is the lateral boundary of the femoral trigone and forms the roof of the adductor canal. It arises from the anterior superior iliac spine and crosses the thigh obliquely downward and inward. On the medial aspect of the thigh it descends almost vertically to an insertion into the proximal part of the medial surface of the tibia. It is a flexor and medial rotator of the leg and an abductor, flexor and lateral rotator of the thigh.

The *quadriceps femoris muscle* (N. femoral, L 3, 4), the powerful extensor of the leg, has four divisions which form a thick muscle mass, em acing the anterior, lateral and medial surfaces of the shaft of the femur (Figs. 904, 931). The manner of insertion of the components of the quadriceps into the base and lateral border of the patella is described on page 1005. The *rectus femoris muscle* arises from a straight head, which originates in the anterior inferior spine of the ilium, and a reflected head from the dorsum of the ilium just above the acetabulum. In the upper part of the thigh it forms the floor of a depression between the tensor fasciae latae and sartorius muscles, and is related closely to the anterior aspect of the capsule of the hip joint. The rectus femoris becomes superficial after being crossed by the sartorius muscle, and forms a well marked rounded elevation in the front of the thigh when the knee is extended. The *vastus intermedius muscle* arises

from the anterior and lateral aspects of the shaft of the femur. It is overlapped partially by the lateral and medial vasti and is covered by the rectus femoris. The *vastus lateralis* has a linear origin from the linea aspera and the proximal part of the shaft of the femur, and constitutes the muscle mass on the lateral aspect of the thigh. The *vastus medialis* arises from the proximal part of the femur and from the linea aspera, and occupies the anterior and medial part of the thigh. On each side of the patella the knee joint capsule is strengthened by tendinous expansions from the medial and lateral vasti.

Adductor Canal (of Hunter) and Its Contents. The *adductor canal* is an intermuscular space on the medial aspect of the middle third of the thigh which contains the femoral vessels and the saphenous nerve. The lateral wall is formed by the vastus medialis muscle, and the posterior wall by the adductor longus muscle proximally and the adductor magnus muscle distally. The roof of the canal is a layer of deep fascia running from the adductor longus and magnus muscles to the vastus medialis muscle. The sartorius muscle covers the space. The canal runs from the apex of the femoral triangle to the tendinous hiatus in the adductor magnus muscle, through which the femoral vessels enter the popliteal fossa.

The *femoral artery* is bound closely by connective tissue to the femoral vein, which at first lies posterior to and then slightly to the lateral side of the artery. The superior geniculate (anastomotica magna) artery branches from the femoral near its termination.

The *saphenous nerve* crosses anterior to the femoral artery and diverges from it at the tendinous hiatus. The nerve passes downward under the sartorius muscle to a distribution over the medial aspect of the leg and ankle.

The incision for *ligation of the femoral artery in the adductor canal* is along a line extending from the midpoint of the inguinal ligament to the adductor tubercle. The incision is deepened through the superficial fascia, and the great saphenous vein is retracted. The thin fascia over the sartorius is divided, and the muscle is retracted medially. The strong fascial roof of the canal is opened, and the femoral artery is exposed with the saphenous nerve on its anterior surface.

After ligation of the femoral artery collateral circulation is established through the anastomosis between the descending branch of the lateral circumflex artery and the superior geniculate (anastomotica magna), and through the connections between the fourth perforating artery and branches of the popliteal artery.

Shaft of the Femur. The shaft of the femur is longer and stronger than that of any other bone. It is inclined downward and medially toward the knee; the obliquity is greater in females than in males because of the proportionately greater width of the female pelvis. The direction of the shaft presents a gentle forward convexity. Its shape is not quite cylindrical, because of the pronounced ridge or *linea aspera*, which projects from its posterior surface. In the distal third of the femur the linea aspera bifurcates into elevations which are continued down to the condyles as the epicondylar ridges. The bone increases in size toward the condyles and assumes an oval outline on cross section.

The shaft is obscured by the muscles covering it, so that actual palpation cannot be performed and ready surgical approach is rendered difficult. The depth of the bone from the anterior surface of the thigh is greatest in its proximal part, but diminishes progressively downward. A cross section through the thigh at the junction of the lower and middle thirds shows the femur altogether within the anterior half of the section (Fig. 932). The absence of large vessels on the lateral or anterolateral aspect of the thigh permits the deep incision necessary for the repair of fractures or the treatment of osteomyelitis. Incision is made parallel or anterior to the lateral intermuscular septum.

The cortex is a thick layer of compact bone about the central medullary cavity. The thickest part corresponds to the linea aspera. The thickness of the cortex decreases progressively in the lower third of the bone until it is reduced to a thin layer at the condyles. The central canal extends from the base of the lesser trochanter to a point about a palmbreadth above the articular surface of the condyles. The main nutrient artery enters the nutrient foramen on the linea aspera above the middle of the shaft and, after traversing the bone obliquely upward for about 5 cm., enters the

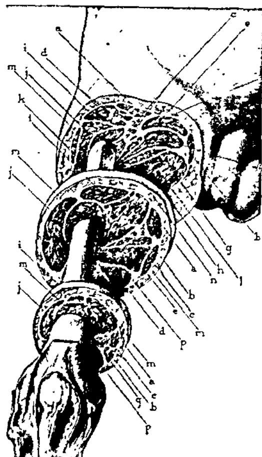


Fig. 932. TRANSVERSE SECTIONS, AT EQUIDISTANT LEVELS, THROUGH THE THIGH, DEMONSTRATING THE STRUCTURES WHICH APPEAR AT REPRESENTATIVE SITES OF AMPUTATION.

Key: *a*, sartorius muscle; *b*, gracilis; *c*, femoral artery and vein; *d*, deep femoral artery and vein; *e*, adductor longus muscle; *f*, adductor brevis; *g*, adductor magnus; *h*, adductor minimus; *i*, rectus femoris; *j*, vastus lateralis; *k*, tensor fasciae latae; *l*, pectineus; *m*, vastus intermedius and vastus medialis; *n*, iliopsoas; *o*, great saphenous vein; *p*, semimembranosus muscle. *(After Lanz and Wachsmuth.)*

medullary canal. A second nutrient foramen may be present farther distally. Of the femoral epiphyses, the lower is the last to unite.

The lower end of the femur is described later (p. 1020).

Posterior or Flexor Region of the Thigh

DEFINITION AND BOUNDARIES. The posterior or flexor region of the thigh represents the soft parts behind the plane of the intermuscular septa (Figs. 932, 933). It is limited laterally by the lateral intermuscular septum, mesially by the plane of the posterior surface of the adductor muscles and by the medial intermuscular septum, above by the inferior border of the gluteus maximus, and below by the upper limits of the popliteal space.

MUSCULATURE. The posterior compartment of the thigh contains the three hamstring muscles and the sciatic nerve with its two terminal branches, the tibial (internal popliteal) and the common peroneal (external popliteal) (Fig. 933).

The hamstring muscles arise from the posterior surface of the ischial tuberosity, and span the long distance between the pelvis and knee with no attachment to the body of the femur except for the short head of the biceps. As a result, these muscles retract more after amputation than do the anterior thigh muscles, which have femoral attachments.

The *biceps femoris muscle*, which runs distally and laterally, has a second or short head of origin from the linea aspera. The common tendon is felt easily through the skin. It descends to an insertion on the head of the fibula, extends the thigh, and is a powerful flexor and a weak lateral rotator of the knee joint. The *semimembranosus muscle* runs distally along the medial side of the posterior compartment of the thigh to insert into the medial condyle of the tibia. The *semitendinosus* is muscular above, but tapers distally into a long tendon which lies in a groove on the posterior surface of the semimembranosus. It inserts into the medial surface of the tibia. Both these muscles extend the thigh and flex the leg, and, with their medial tibial insertion, produce a slight amount of medial rotation at the knee joint.

The posterior group of femoral muscles is supplied by the sciatic nerve (L 4, 5; S 1, 2, 3), but the nerve to the short head of the biceps may arise from the common peroneal (external popliteal) nerve (L 4, 5; S 1).

VESSELS AND NERVES. The perforating branches of the *profunda femoris artery* (p. 960) enter the posterior portions of the thigh through openings in the adductor magnus muscle, close to its insertion into the linea aspera. They wind posteriorly about the bone to supply the hamstring muscles and much of the vastus lateralis. Hemorrhage from operations on the shaft of the femur is difficult to control because of the depth of the source of the bleeding. The first perforating artery, besides forming longitudinal loop anastomoses, enters into the crucial anastomosis (p. 927).

The third and fourth perforating arteries anastomose with the proximal muscular rami of the popliteal artery.

The superficial *lymphatics* drain into the superficial subinguinal lymph nodes, and the deep lymphatics follow the inferior gluteal vessels to the hypogastric lymph nodes in the pelvis. Two nerves run down the axis of the posterior compartment of the thigh. The *posterior cutaneous nerve* (*small sciatic*) runs deep to the enveloping fascia, and its branches supply the overlying skin. The *sciatic nerve* (*great sciatic*) is the continuation of the flattened band of the sacral plexus and descends between the greater trochanter of the femur and the tuberosity of the ischium. It is overlaid proximally by the long head of the biceps muscle, and below is overlapped by the semimembranosus muscle. Early in its course it supplies the hamstring and the adductor magnus muscles. It terminates in the middle third of the thigh by dividing into the common peroneal and tibial nerves (Fig. 933).

The *surgical approach to the sciatic nerve* is along the axial line of the femur from a point midway between the greater trochanter and the ischial tuberosity and the apex of the popliteal fossa. In the proximal part of the incision the inferior margin of the gluteus maximus muscle is exposed and retracted superiorly. The nerve is located in a mass of fatty tissue after retracting the relaxed hamstring muscles

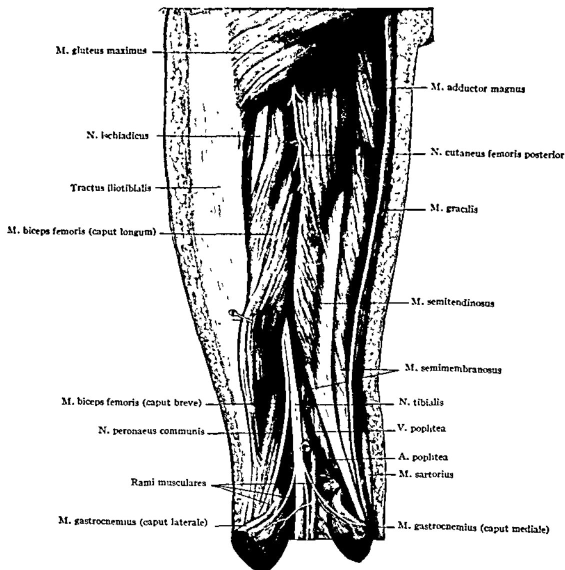


Fig. 933. STRUCTURES OF THE POSTERIOR REGION OF THE THIGH AND THE POPLITEAL SPACE.

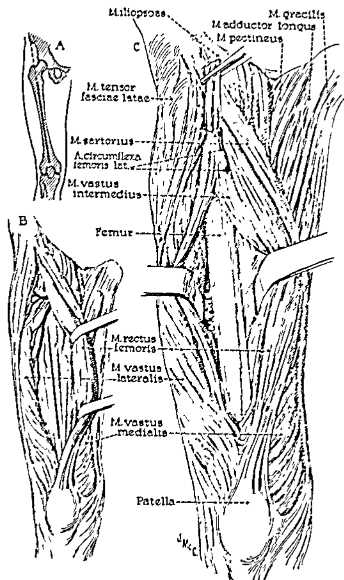


Fig. 934. ANTERIOR OR ANTEROLATERAL APPROACH TO THE MIDDLE THIRD OF THE FEMUR.

A, The skin incision is made along a line from the anterior superior spine to the lateral margin of the patella. *B*, The superficial and deep fasciae are incised, and the rectus femoris and vastus lateralis muscles are separated along their intermuscular septum, thus exposing the vastus intermedius muscle. *C*, The vastus intermedius is incised in the direction of its fibers down to the femur and reflected subperiosteally, giving a good exposure of the anterior and anterolateral aspects of the bone. Extending this incision much higher runs the risk of injuring the lateral circumflex femoral vessels and the nerve to the vastus lateralis muscle. Distally, the incision reaches to within 5 or 6 inches of the knee joint.

medially. In the midportion of the thigh the groove between the diverging hamstring muscles is identified, and the nerve is exposed by retracting the long head of the biceps laterally.

APPROACHES TO THE FEMUR. The anterior or anterolateral approach (Fig. 934) and the lateral or posterolateral approach (Fig. 935) to the shaft of the femur provide good exposure for any operation. Because the anterior approach interferes more with quadriceps function, with a possible consequent delay in knee motion, the posterolateral approach is most commonly used. The anterolateral approach is also liable to carry with it much more hemorrhage than the posterolateral approach. In treating a fracture of the femur, when there may have already been sufficient bleeding, if there is a choice in approaches, the posterolateral approach would be the safer one to use and carries with it less risk of shock.

FRACTURES OF THE SHAFT OF THE FEMUR. Fractures of the femoral shaft present problems somewhat like those involved in fracture of the humerus. There is no splinting bone,

and the powerful muscles, some of which span the femur, cause characteristic angulation and overriding.

Although subject to a variety of strains, the femur usually is broken by direct violence. The fracturing force may act indirectly, as it does in a fall upon the knee or in powerful twists, such as may occur when the body is turned to one side with the foot held firm. Fractures from direct violence, as a rule, are transverse, or nearly so; spiral or long oblique fractures are fairly common. Fragment displacement is greater in fractures from indirect violence than in those from direct violence, in which the break tends to be transverse. The degree of displacement depends upon the direction of the injuring force, the line of fracture, the muscle pull and the influence of the weight of the limb. The most powerful muscles effecting the displacement are the adductors and hamstrings. The entire femur may be regarded as a rigid arc, subtended by a mass of muscles upon the medial and posterior aspects of the thigh. Consequently, when the shaft breaks, these two groups of muscles tend to approximate the extremities of the bony arc, with the result that the distal fragment is drawn up beneath the proximal fragment (Fig. 936). An angular deformity results. The summit of the angle most frequently is directed

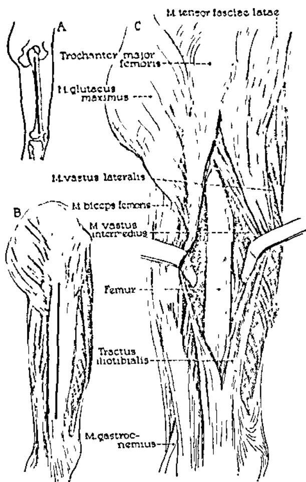


Fig. 935. LATERAL AND POSTEROLATERAL APPROACH TO THE SHAFT OF THE FEMUR.

A, Incision of the desired length is made on the lateral aspect of the thigh on a line between the greater trochanter and the external condyle. *B*, For the posterolateral approach some surgeons prefer an incision along the posterior edge of the femoral shaft. For the straight lateral approach the iliotibial tract is divided in the midline, and the vastus lateralis and vastus intermedius muscles are divided in the direction of their fibers down to the periosteum, which is incised and reflected for the desired length. *C*, For the posterolateral approach, which permits easier exposure of any portion of the shaft of the femur, the iliotibial tract is divided along its posterior edge and retracted anteriorly to the lateral intermuscular septum, from which the vastus lateralis muscle is separated down to the femur and retracted anteriorly. The periosteum can be incised in the direction of the incision and reflected.

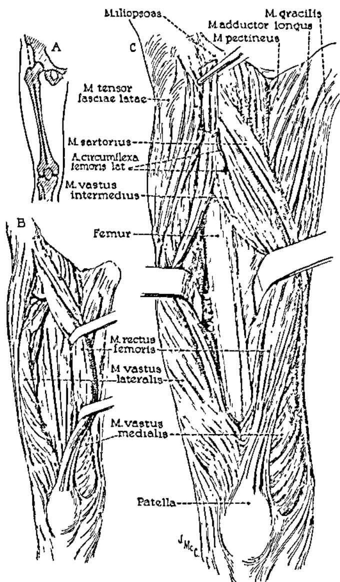


Fig. 934. ANTERIOR OR ANTEROLATERAL APPROACH TO THE MIDDLE THIRD OF THE FEMUR.

A, The skin incision is made along a line from the anterior superior spine to the lateral margin of the patella. *B*, The superficial and deep fasciae are incised, and the rectus femoris and vastus lateralis muscles are separated along their intermuscular septum, thus exposing the vastus intermedius muscle. *C*, The vastus intermedius is incised in the direction of its fibers down to the femur and reflected subperiosteally, giving a good exposure of the anterior and anterolateral aspects of the bone. Extending this incision much higher runs the risk of injuring the lateral circumflex femoral vessels and the nerve to the vastus lateralis muscle. Distally, the incision reaches to within 5 or 6 inches of the knee joint.

medially. In the midportion of the thigh the groove between the diverging hamstring muscles is identified, and the nerve is exposed by retracting the long head of the biceps laterally.

APPROACHES TO THE FEMUR. The anterior or anterolateral approach (Fig. 934) and the lateral or posterolateral approach (Fig. 935) to the shaft of the femur provide good exposure for any operation. Because the anterior approach interferes more with quadriceps function, with a possible consequent delay in knee motion, the posterolateral approach is most commonly used. The anterolateral approach is also liable to carry with it much more hemorrhage than the posterolateral approach. In treating a fracture of the femur, when there may have already been sufficient bleeding, if there is a choice in approaches, the posterolateral approach would be the safer one to use and carries with it less risk of shock.

FRACTURES OF THE SHAFT OF THE FEMUR. Fractures of the femoral shaft present problems somewhat like those involved in fracture of the humerus. There is no splinting bone,

the thigh on the pelvis, and the posterior muscles are relaxed by flexion of the knee on the thigh.

Fracture of the middle third of the shaft is treated more easily than fracture of the proximal third because of the greater length and the more superficial position of the proximal fragment. The displacement is caused by the same forces that act upon fracture through the proximal third, and is similar, save that there is less tendency toward overriding and more toward angulation. As a rule, however, the distal fragment slides upward, behind, and medial to the proximal fragment. In fracture produced by indirect violence the fragment ends sometimes are pointed and sharp, and become embedded in the muscles and deep fascia, rendering reduction difficult.

Fractures through the shaft of the femur can be successfully treated by traction in a Thomas or Hodgen splint. Because of the time required for healing to take place and for the traction to be maintained, skeletal traction is preferable to skin traction. If the fracture is proximal to the juncture of the middle and lower thirds of the femur, skeletal traction by means of a threaded wire, preferably, or a Kirschner wire or Steinmann pin can be placed through the point of election in the lower femur, beginning at a point one inch proximal to the adductor tubercle. If the fracture or the hematoma is too far distal to permit placement of a pin through the distal femur, so that the pin would not pass through either the fracture site or the hematoma, it is then necessary to place the pin through the proximal tibia at the point of election, which is just posterior, through the tibia to the anterior tibial tubercle. In either case the knee is held flexed at 20 to 30 degrees. This is particularly important when dealing with a supracondylar fracture, which would have the pull in flexion of the distal condylar fragment because of the pull of the gastrocnemius muscles. In infants and children under five years of age overhead traction by means of skin applied to both legs with sufficient traction applied just to elevate the buttocks from the bed may be satisfactorily used. This type of traction, however, is dangerous in children over five years of age, or even large children over four years of age. This traction must be carefully watched because of the possibility of serious circulatory accident.

In *fracture of the distal third of the shaft* the distal fragment is tilted backward by the gastrocnemius muscle; the nearer the fracture is to the condyles, the more marked is the tilting. This fragment is drawn upward *behind the proximal fragment by the quadriceps* femoris and hamstring muscles (Figs. 936, 937). The popliteal artery and the common peroneal (external popliteal) nerve may be lacerated or may be stretched over the sharp proximal edge of the distal fragment. The artery lies deeper and is more liable to injury. The thigh appears shortened and thickened, and the swelling from hemorrhage soon obscures the bony deformity. Slight rotary movements show that the trochanter fails to move with the distal fragment of the shaft.

Reduction is effected by skeletal traction through the femoral condyles; the knee must be flexed to relax the gastrocnemius muscle and allow the distal fragment to tilt forward to its normal position. Since traction causes a downward tilting of the pelvis on the affected side, and hence a relative abduction of the distal fragment, a genu valgum may be produced. If the fracture is too close to the con-

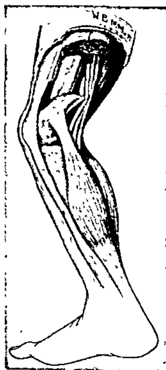


Fig. 937. FRACTURE OF THE DISTAL THIRD OF THE SHAFT OF THE FEMUR.

The posterior displacement of the distal fragment by the gastrocnemius muscle endangers the popliteal vessels and nerves. (From Babcock: Textbook of Surgery.)

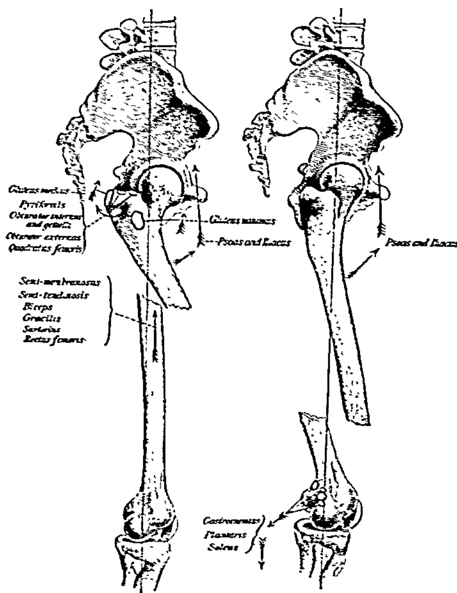


Fig. 936. MECHANISM OF THE DISPLACEMENT OF THE FRAGMENTS IN FRACTURE OF THE UPPER AND LOWER THIRDS OF THE SHAFT OF THE FEMUR.

(Deaver, after Nifong.)

forward, or forward and laterally. With this deformity there is a considerable degree of shortening. The correction of shortening is one of the main problems encountered in the treatment of femoral fracture. In spite of the bulk of thigh muscles, femoral fractures frequently are open.

In *fracture of the proximal third of the femur*, anterior and lateral displacement of the proximal fragment usually is marked, since this fragment is drawn forward by the iliopsoas and pectineus muscles and is abducted and rotated laterally by the muscles attached to the greater trochanter (Fig. 936). The forward tilting of the proximal fragment is increased by the forward push of the distal fragment, which is drawn upward behind the proximal fragment by the hamstring and adductor muscles. The distal fragment is rotated laterally by the adductors and the weight of the everted foot.

The short, deeply placed proximal fragment is difficult to manipulate into position. To correct displacement and bring the distal and proximal fragments into apposition, traction in wide abduction is usually necessary. Skeletal traction from the femoral condyles readily brings the fragments to proper length. The anterior muscles are relaxed by flexion of

an obliquely circular incision with the low point posteromedial where the muscles retract the most, and the high point anterolateral where retraction is least. The incision ends up as a transversely circular incision. In transverse sections through the middle third of the thigh the femoral and profunda vessels are located in the muscles at the inner side of the divided femur. The descending branches of the lateral circumflex vessels, which run downward in the substance of the vastus lateralis muscle, some muscle branches of the femoral vessels and the perforating branches of the profunda vessels may require ligation. The sciatic nerve is recognized readily in the midst of the hamstring muscles. It is advisable to retract the nerve from the loose connective tissue which surrounds it, and to remove enough of it to ensure its remaining deeply buried between the muscles when it is released. If it comes sufficiently near the end of the stump to be subjected to pressure, it subsequently develops a painful bulbous extremity known as an amputation neuroma.

A successful *amputation through the lower third* of the thigh is that described by Callander* (Figs. 939 to 941). The patient is placed in the dorsal decubitus position, the knee of the affected extremity is flexed slightly, and the leg is elevated a little above the horizontal on one or two sandbags. No tourniquet is applied. The surgeon stands on the side opposite the affected extremity and faces the medial aspect of the thigh and knee to be operated upon. He maintains this position throughout the operation, because the essential steps are directed through a medial approach to the popliteal space. The operative work on the lateral aspect of the lower part of the thigh and knee is accomplished readily by rotating the knee medially.

The incisions in the skin outlining the slightly unequal anterior and posterior flaps coincide with the incisions that sever all the deeper soft parts (Fig. 939). The incision on the medial aspect of the thigh begins at a point three fingerbreadths proximal to the most prominent part of the medial femoral condyle, and runs horizontally distally in the palpable groove between the vastus medialis and the sartorius muscles. With the knee in partial flexion, this groove can be defined readily. After the incision has been deepened to the enveloping or deep fascia of the thigh the adductor tubercle of the medial femoral condyle and the tendon of the adductor magnus muscle, which inserts on it, can be palpated. The incision in the skin continues distally over the medial condyle, sweeps forward and crosses the anterior surface of the tibia at the anterior tibial tuberosity, the point of insertion of the quadriceps extensor tendon.

The thigh then is rotated medially (i.e., toward the surgeon). The incision on the lateral aspect of the leg begins at a point three fingerbreadths proximal to the lateral femoral condyle in the palpable groove between the tendon of the tensor fasciae latae (iliotibial tract) and the biceps femoris muscles. This incision must overlie and split the tensor fasciae latae tendon in order to avoid the muscle fibers of the biceps. Continuing distally over the lateral epicondyle, the incision extends forward to meet the medial incision at the interior tibial tuberosity, thus outlining the anterior flap of the amputation.

Corresponding incisions from each femoral epicondyle are carried obliquely, posteriorly and inferiorly until they meet on the calf of the leg at a point considerably inferior to the level of the anterior tibial tuberosity, about the midpoint of the belly of the gastrocnemius muscle. This incision for the posterior flap is deepened to the fascia on the gastrocnemius muscle. Thus are outlined two long amputation flaps, the posterior a little longer than the anterior. Each flap partakes not only of the soft parts of the lower thigh, but also of a considerable portion of the soft parts of the leg.

Attention then is centered again on the medial aspect of the thigh and knee. The horizontal portion of the medial incision, common to the two flaps (i.e., that portion lying between the vastus medialis and the sartorius muscles) is deepened through the deep fascia of the thigh. Division of this powerful fascial layer, which is the only strong structure in the medial wall of the popliteal fossa at this level, affords ingress to the popliteal space. The left forefinger, now inserted into the superficial popliteal space, by blunt dissection frees the medial hamstring tendons as far as their tibial insertions. At this juncture

* Callander: A New Amputation in the Lower Third of the Thigh, J.A.M.A., 105: 1746–1753, 1935; Tendoplastic Amputation through the Femur at the Knee. J.A.M.A., 110: 113–117, 1938.

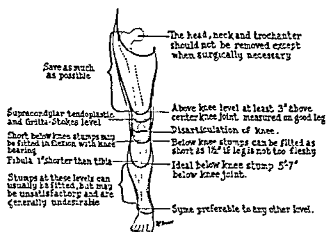


Fig. 938. SITES OF ELECTION FOR MAJOR AMPUTATIONS OF THE LOWER EXTREMITY, AND ESSENTIAL POINTS IN AMPUTATIONS.

The operation should be done with the use of a tourniquet whenever possible. Definitive operation should be done in a clean field and under careful aseptic precautions. Except in end-bearing stumps, the skin flaps should be cut equal in length so that they meet in the center of the end of the stump, without redundancy. A general rule for estimation of the length of the skin flaps is to cut each flap approximately two thirds of the length of the radius of the limb. The stretching of the flaps, which then results after undercutting, permits them to lengthen sufficiently for closure. The deep layer of fascia is reflected with the skin flap in primary amputation whenever possible. The muscles are divided slightly distal to the saw line, so that, after retraction has taken place, the ends of the muscles will be at the level of bone section. The periosteum is sharply divided at the level of bone section. The main nerves are gently pulled down, smoothly divided, and allowed to retract out of the stump end. Nerves are not ligated, cauterized, injected or otherwise treated by any fancy technique. The tourniquet should be removed after the main vessels have been ligated and complete hemostasis obtained. The skin flaps are closed by simple interrupted skin sutures. The use of subcutaneous and stay sutures is not only unnecessary, but contraindicated in that they further traumatize already ischemic flaps. Drainage should be used more or less routinely for twenty-four to forty-eight hours in all amputation stumps because of the tendency for the postoperative collection of blood or serum, or both, from the mass of sectioned muscle and bone. (From Alldredge: Surg., Gynec. & Obst., 84: 759–64, 1947.)

dyles for the use of skeletal traction on the condyles, reduction is attempted by manipulation; the fragments are immobilized with the knee at a right angle or less, and with the thigh partially flexed on the pelvis. Skeletal traction may be effected with pin or wire passed through the proximal portion of the tibial crest. The knee joint, which is peculiarly prone to stiffening after prolonged fixation, is safeguarded partially when skeletal traction is applied to the femoral condyles, since, in this method of treatment, motion at the knee is not hindered.

Amputation through the Thigh. Unless there are definite contraindications, the site of election for amputation through the thigh is through the lower third, where a stump, admirably adapted to the adjustment of a prosthesis, is obtained (Fig. 938). The shortest satisfactory amputation in the upper third of the thigh requires a 7.5-cm. stump, for it is almost impossible to fit a stump of less length with a prosthetic device. Unless an end-bearing prosthesis is to be used, it should be remembered that a distance of at least 3 inches is necessary to assure a proper knee joint in a prosthesis to make the knee equal in length to the opposite leg. This is particularly true if a suction-socket type of prosthesis is contemplated.

In thigh amputations certain anatomic points are of interest. Because of the great mobility of the skin and subcutaneous tissue over the fascia lata, superficial flaps are raised easily at any level of the limb. The muscles, from the viewpoint of amputation, form the principal bulk of the limb and constitute two groups. The first group consists of those which are invested by loose areolar tissue and which have no fixed attachment to the femur. It includes the sartorius, gracilis and hamstring muscles, with the exception of the short head of the biceps. These muscles lie in the medial and posterior parts of the thigh and retract freely when divided. The second group includes those muscles attached to the femur—the quadriceps femoris group and the three adductors. When these are divided, they retract to a much less extent than do the muscles of the first group. This variation in retraction is used in modifying the circular incision for supracondylar amputation of the femur to

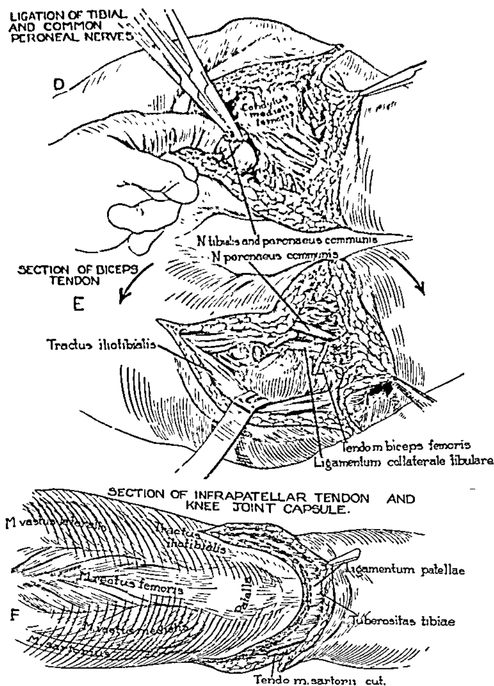


Fig. 940. CALLANDER'S TENDOPLASTIC AMPUTATION THROUGH THE FEMUR AT THE KNEE (CONTINUED).

D, The tibial and common peroneal nerves are hooked into the wound with the index finger prior to section. *E*, The lateral side of the knee is rotated medially toward the surgeon, who always stands throughout the operation on the side opposite the extremity operated upon. The biceps tendon is sectioned. *F*, The quadriceps extensor apparatus is sectioned at its tibial insertion. Incision likewise is carried through the quadriceps aponeurotic expansions.

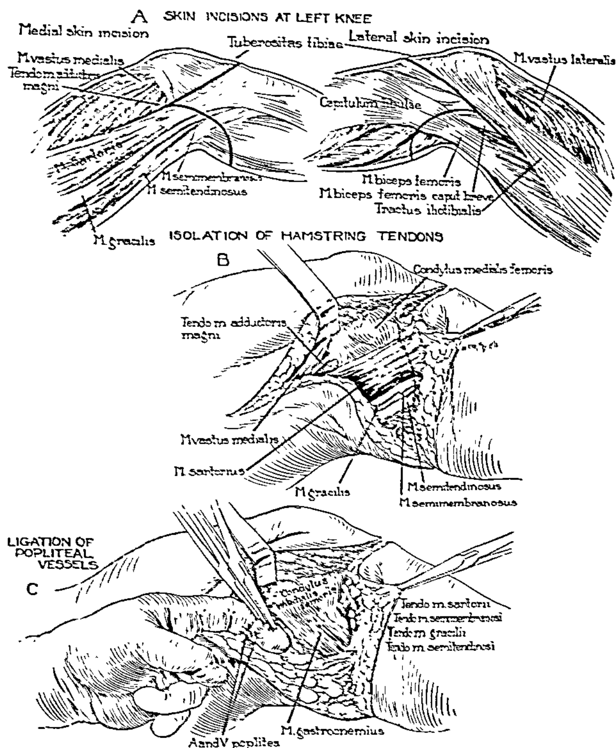


Fig. 939. CALLANDER'S TENDOPLASTIC AMPUTATION THROUGH THE FEMUR AT THE KNEE.

A, Skin incisions indicate that the skin and subcutaneous tissues of the leg enter into flap formation. It is evident that the hamstring muscles are cut through their tendinous insertions. *B*, Fleshy portion of medial hamstring muscles exposed to show anatomic location. Only the tendinous portions are exposed during operation. *C*, The medial hamstring muscles have retracted after section, exposing the popliteal space widely for ligation of the popliteal vessels.

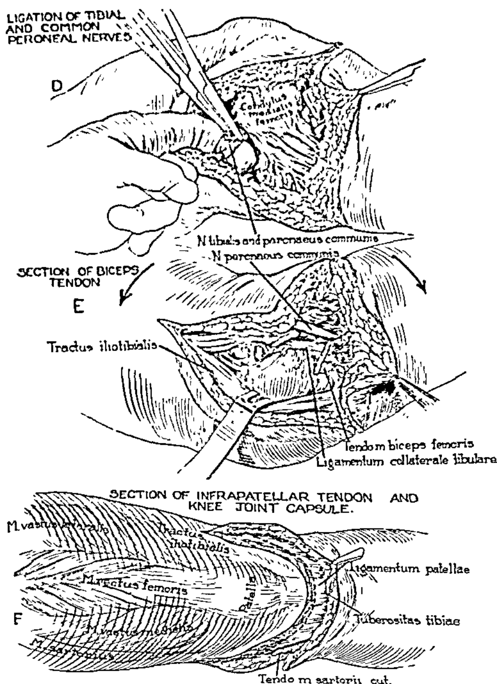


Fig. 940. CALLANDER'S TENDOPLASTIC AMPUTATION THROUGH THE FEMUR AT THE KNEE (CONTINUED).

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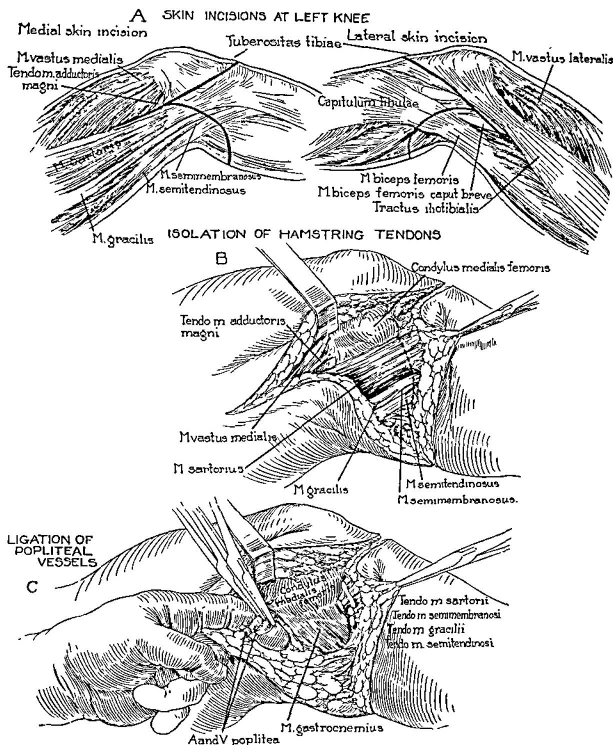


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these tendons are divided in the order named: sartorius, gracilis, semimembranosus and semitendinosus. During this dissection no fleshy portion of any of the medial hamstring muscles, nor any part of the vastus medialis muscle, need be exposed, much less severed. The severed hamstring tendons retract at once into the aponeurotic and areolar tissue of the posterior flap, and are not dealt with again. Further exposure is gained by severing the tendon of the adductor magnus muscle at its attachment to the adductor tubercle. Free access to the vasculoneural contents of the popliteal space is thus afforded. Moderate flexion of the knee relaxes the popliteal vessels and nerves and favors their manipulation. With a finger now inserted more deeply into the popliteal space and kept close to the posterior surface of the femur, the popliteal artery and vein are withdrawn easily to a level flush with, or even outside of, the incision in the skin. Here they are clamped, ligated, and divided as far proximally in the popliteal space as possible (Fig. 940, *D*, *E*). The tibial (internal popliteal) and common peroneal nerves are then drawn readily into the wound as one trunk and are anesthetized, ligated, divided, and allowed to retract into the proximal recess of the popliteal space. Ligation of these three essential structures low down in the popliteal space prevents unnecessary separation of the posterior flap from the femur and minimizes formation of dead space.

The partly flexed knee is then rotated toward the surgeon, and the lateral longitudinal incision is deepened through the more posterior fibers of the tensor fasciae latae tendon. This incision is carried inferiorly as far as the insertion of the biceps muscle on the head of the fibula, where the biceps tendon then is severed. At this stage of the operation the popliteal space may be opened widely from side to side, since the essential structures have been divided. Deepening of the incision outlining the posterior flap down to the gastrocnemius aponeurosis and clearing from it the areolo-adipose debris free the posterior flap. It is advantageous to leave as much as possible of the fibro-areolar tissue of the popliteal space in contact with the femur as far distally as the level of the adductor tubercle in order that there may be but little dead space between the posterior flap and the femur.

The knee is then extended, and the incision marking the distal portion of the anterior flap is deepened through the capsule of the knee joint down to the femoral condyles and to the tibia, thereby severing the quadriceps

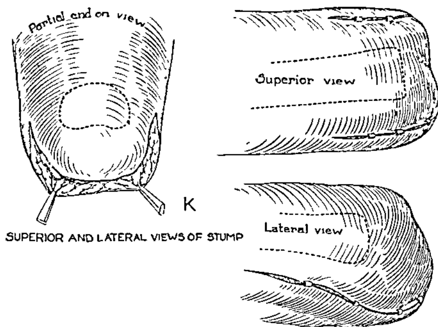


Fig. 942. CALLANDER'S TENDOPLASTIC AMPUTATION THROUGH THE FEMUR AT THE KNEE (CONCLUDED).
K, Indicates the redundant amputation flaps and the loose closure of the suture line.

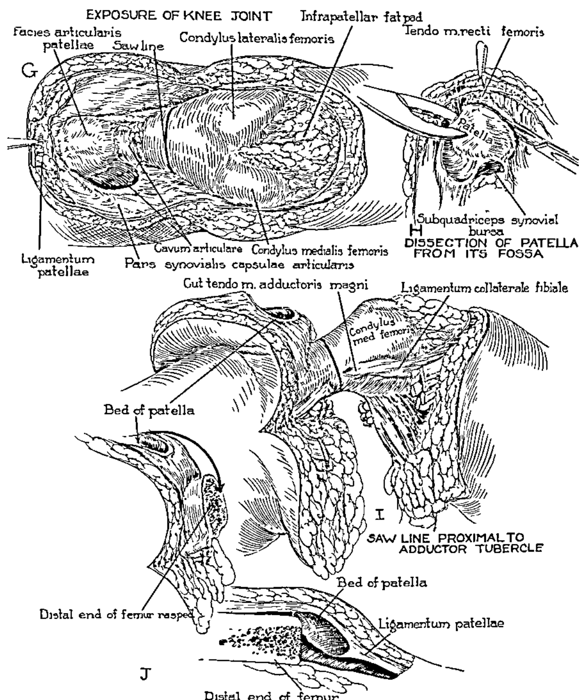


Fig. 941. CALLANDER'S TENDOPLASTIC AMPUTATION THROUGH THE FEMUR AT THE KNEE (CONTINUED).

G, Knee joint exposed and saw line on the femur indicated. Saw line an inch more proximal on the shaft than line indicated gives a shorter stump, and one better adapted to a prosthesis. *H*, Patella is removed from its fossa by sharp and blunt dissection. Removal is easier from the apex to the base. *I*, *J*, Patellar fossa falls naturally over sectioned end of the femur.

tendon at its insertion into the tibial tuberosity (Fig. 940, *F*). The anterior flap, containing the patella, is dissected upward off the infrapatellar fat pad and drawn upward on the thigh until the superior synovial recesses of the subquadriceps space are seen. The patella is dissected from the apex to the base from its sesamoid position in the quadriceps tendon, care being taken to preserve the longitudinally disposed tendon of the rectus femoris muscle, which runs over it. Preservation of this tendon adds materially to the end-bearing capacity of the stump after the cut end of the femur has been fitted into the socket from which the patella was removed. The synovia on the anterior flap and on the femur proximal to the condyles is not excised. The femur now is sawed through its cancellous portion just proximal to the adductor tubercle (Fig. 941, *G*). At this level the shaft of the femur corresponds in size to the patellar socket in the quadriceps tendon. The cut end of the femur is rounded with a bone-cutting forceps and a rasp until no sharp surfaces and no fringes of periosteum remain.

The two large flaps are inspected for small bleeding points. These can be ascertained best by sluicing the surfaces of both flaps with large quantities of warm salt solution. The flushing has the additional advantage of washing away any soft tissue or bone debris. Many small bleeding points may require ligation after this procedure. Inspection of the body of the posterior flap shows no muscle fibers. It does show areolo-adipose tissue and the cut ends of the hamstring tendons, which already are retracted into their aponeurotic beds and scarcely are visible. The flaps are now allowed to fall loosely together.

The coaptation suturing during operation is limited to placing six or eight clips or sutures at such intervals as to keep the flaps in fair apposition (Fig. 942). When the edges of the skin are approximated, the aponeurotic edges lie in contact also; mere apposition is sufficient to produce firm union. None of the tendons or aponeuroses of the anterior flap are sutured to the corresponding structures of the posterior flap. In this way no structure is under any tension, and the trauma and consequent pressure necroses which result from suture of these deeper structures cannot occur. The flaps appear exceedingly long and even extend 1 or more inches beyond the end of the femur immediately after they have been fashioned. To the surgeon accustomed to the routine type of amputation in the lower third of the femur, the flaps appear excessively redundant and clumsy and arouse suspicion that a bulbous stump end and large dead spaces will result. When he notes how wobbly the femur lies between the flaps, he questions whether the end will gain contact with the patellar socket and fuse there. As early as the second or third postoperative day, and sometimes even within a few hours after the operation, the reason for leaving these flaps under no tension becomes apparent, since the hamstring muscles, severed only at their distal attachment, contract to the degree that the cutaneous suture line lies posteriorly about the level of the stump end, and the femur is felt in the patellar fossa.

A simple *supracondylar tendoplastic amputation* of the thigh gives excellent results. This can be made with a long anterior and a short posterior skin and fascial flap (Fig. 943), but flaps of equal length assure equal blood supply, and the scar in the center of the stump will have little contact with the socket of the prosthesis.

The *Gritti-Stokes amputation* is performed at the same level as the supracondylar tendoplastic amputation, but is designed so that the patella, with its articular surface sawed off, will fit over the end of the femur and subsequently unite with sound bony union. If this occurs, an excellent amputation stump results, but union of the patella to the femur often fails, thus requiring reoperation.

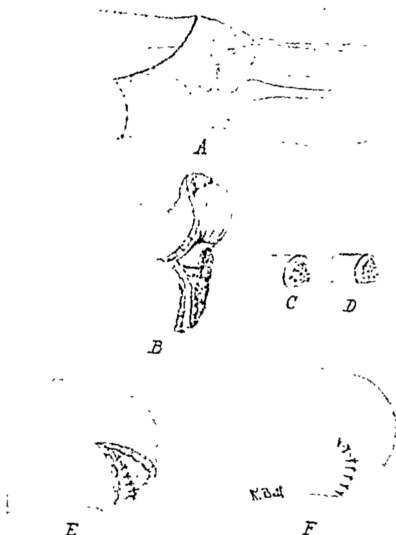


Fig. 943. SUPRACONDYLAR TENDOPLASTIC AMPUTATION (KIRK).

A, The relation of the long anterior and short posterior skin flaps to the femur, patella and contour of the thigh is important. The line of bone transection is just above the condyles. *B*, The anterior flap includes the quadriceps tendon divided at the patella. The underlying synovia is resected. The posterior fascia is cut ¼ to ½ inch distal to the skin incision, and the muscles are sectioned to the bone. The soft parts are retracted and the femur sawed through cleanly at the desired level. *C*, A ¼-inch cuff of periosteum is removed. This is not commonly done now, since aseptic necrosis and separation of a ring of bone have followed removal of the periosteum. *D*, The bone edges are rounded. The major vessels are isolated and doubly ligated. The sciatic nerve is drawn down, ligated and sectioned high. Ligation of the nerve is frequently omitted, and the older procedure of injecting the nerve with alcohol is not done now. If a tourniquet has been used, it is now removed and hemostasis obtained. *E* and *F*, The fascial and skin flaps are carefully approximated with interrupted sutures.

Skin flaps of equal length are commonly used nowadays to assure good blood supply, and the scar on the end of the stump will be away from the sides of the prosthetic socket. The plan of *A* is easily changed to a short fish-mouth incision, making two equal flaps.

The lateral and medial parapatellar grooves are succeeded below by a fullness on each side of the patellar ligament which is accentuated by contraction of the quadriceps muscle. This fullness is caused by the intra-articular, extrasynovial *fat pad* wedged into the interval between the patellar ligament, the head of the tibia, and the femoral condyles. When the leg is extended, the fat pad conveys a sense of fluctuation to the examining fingers, especially in the transverse direction, and may be mistaken for an effusion. Another source of swelling in this region is the *infrapatellar bursa*, which lies between the patellar ligament and the upper part of the tibia. A fluctuant bursa may project to each side of the ligament.

The *joint line* between the femur and tibia is palpated most readily on each side of the patellar ligament. Laterally, the joint line is indistinct because of the resistance and tenseness of the collateral (lateral) ligaments. By displacing the patella inward or outward, the outer and inner lips and part of the anterior articular surface of the femur can be palpated. Both these margins become thickened or lipped in certain varieties of arthritis. By flat palpation over the joint line the degree of thickening of the joint capsule can be determined.

The outer surface of the *lateral condyle of the femur* is crossed by the lower part of the *iliotibial band* of the fascia lata and by the *tendon of the biceps* as it descends to its insertion into the *head of the fibula.* The *common peroneal* (*external popliteal*) *nerve,* which follows the medial aspect of the biceps tendon into the popliteal space, becomes superficial at this level and can be rolled under the finger where the nerve passes behind the head of the fibula. The prominent anterior part of the *lateral tibial condyle* can be felt in front of the head of the fibula at a somewhat higher level. The iliotibial band inserts into it.

The prominent *medial condyle of the femur* can be felt on the medial side of the knee. Above and deeply placed, the *adductor tubercle* marks the lower point of insertion of the adductor magnus tendon into the femur. This is an accurate guide to the distal epiphysial line, which runs horizontally just above the trochlear surface of the femur. Behind the medial epicondyle, the *sartorius muscle* and *gracilis tendon* curve about the medial aspect of the condyle, and then incline almost directly forward and insert into the upper and medial aspect of the tibial shaft. At the knee these tendons are related closely to those of the semimembranosus and semitendinosus muscles.

In active extension of the leg the tendon of the *rectus femoris muscle* forms a tense band which is inserted into the proximal border of the patella. The *vastus medialis muscle* forms a prominent elevation on the medial side of the rectus tendon, and the vastus lateralis muscle, a similar bulge on the lateral side at a more proximal level. Disuse atrophy of the vastus muscles calls attention to more or less painful joint conditions with limited joint function. A very evident depression lies distal to the bulge formed by the lateral vastus muscle between the rectus femoris muscle medially and the iliotibial tract laterally. With the leg in relaxed extension, as in reclining, the whole quadriceps apparatus relaxes, the suprapatellar depression is deeper, the bulges of the vasti are less prominent, and the patella can be moved freely.

When the leg is flexed, the patella at first becomes more prominent, but as the move-

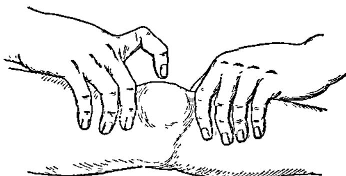


Fig. 944. ELICITING THE "TAP" OR "CLICK" OF THE FLOATING PATELLA IN SYNOVITIS OF THE KNEE.
The hands are used to gather the fluid under the floated patella so that the index finger may percuss and elicit the "tap" or "click." (Moorhead.)

CHAPTER 36

Knee

The region of the knee is bounded superiorly by a line drawn around the thigh at a level three *fingerbreadths superior to the base of* the patella. Its inferior limit is at the level of the distal part of the tibial tuberosity. The knee presents three regions: an anterior or quadriceps extensor region, a posterior or popliteal region, and the bones and joint of the knee, including the superior tibiofibular joint.

Anterior or Quadriceps Extensor Region

The anterior or quadriceps extensor region (Fig. 931), composed entirely of soft parts, offers protection as well as direct access to the knee joint. It constitutes the terminal part of the extension apparatus of the quadriceps muscle, and is homologous to the triceps-olecranon extension apparatus at the elbow.

LANDMARKS. The surface markings over a region as important as the knee require detailed study, since familiarity with them facilitates proper interpretation of the varied and extensive pathologic conditions which alter them. The knee joint is covered thinly on each side and in front (Fig. 931); the bones forming it can be examined easily, any deviation from the normal contour is detected readily, and certain forms of articular disease can be diagnosed at a comparatively early stage. The landmarks at the knee vary greatly according to whether the leg is extended or flexed, so that it is necessary to study each attitude separately. The patella, because of the inelasticity of the ligamentum patellae, lies at a constant distance from its insertion into the tibial tuberosity, whether the knee is flexed or extended (Fig. 945).

When the leg is extended, it does not lie in the axis of the thigh, but forms an obtuse angle, open laterally. The angle varies considerably, but ordinarily measures about 170 degrees. The angulation is more striking in *females* because of the greater medial obliquity of the femur, and is greatly accentuated in the deformity of genu valgum or knock knee. The *patella* projects prominently in front, and its outline is defined readily. When the quadriceps muscle is at rest, the patella enjoys a free range of motion and may be moved from side to side, proximally and distally. The tendon of the rectus femoris muscle may be traced to the upper border of the patella, and the *ligamentum patellae* can be felt from its attachment at the apex of the patella to its attachment at the tuberosity of the tibia (Fig. 931). The tendon is about 5 cm. long, and its midpoint corresponds to the level of the knee joint. When the joint is distended with fluid, the articular surfaces of the patella and femur are separated. A gentle tap on a "floating patella" causes it to knock against the femur (Fig. 944).

Between the lateral margins of the patella and the corresponding femoral condyles are longitudinal depressions, the *lateral* and *medial parapatellar grooves*. If the subcutaneous fat is abundant, these depressions are obliterated. When the rectus femoris muscle is relaxed, as in passive extension, the lateral grooves are connected by a shallow groove above the base of the patella, giving the bone the appearance of being bounded by a horseshoe-shaped peripatellar groove. Beneath the grooves lie the upper and lateral prolongations of the synovial membrane of the knee joint. When the peripatellar groove becomes distended with blood or an inflammatory effusion, the superficial depressions are replaced by a crescentic swelling which almost encircles the patella. Aspiration of the knee joint may be done through any part of this crescent.

The lateral and medial parapatellar grooves are succeeded below by a fullness on each side of the patellar ligament which is accentuated by contraction of the quadriceps muscle. This fullness is caused by the intra-articular, extrasynovial *fat pad* wedged into the interval between the patellar ligament, the head of the tibia, and the femoral condyles. When the leg is extended, the fat pad conveys a sense of fluctuation to the examining fingers, especially in the transverse direction, and may be mistaken for an effusion. Another source of swelling in this region is the *infrapatellar bursa*, which lies between the patellar ligament and the upper part of the tibia. A fluctuant bursa may project to each side of the ligament.

The *joint line* between the femur and tibia is palpated most readily on each side of the patellar ligament. Laterally, the joint line is indistinct because of the resistance and tenseness of the collateral (lateral) ligaments. By displacing the patella inward or outward, the outer and inner lips and part of the anterior articular surface of the femur can be palpated. Both these margins become thickened or lipped in certain varieties of arthritis. By flat palpation over the joint line the degree of thickening of the joint capsule can be determined.

The outer surface of the *lateral condyle of the femur* is crossed by the lower part of the *iliotibial band* of the fascia lata and by the *tendon of the biceps* as it descends to its insertion into the *head of the fibula*. The *common peroneal* (*external popliteal*) *nerve*, which follows the medial aspect of the biceps tendon into the popliteal space, becomes superficial at this level and can be rolled under the finger where the nerve passes behind the head of the fibula. The prominent anterior part of the *lateral tibial condyle* can be felt in front of the head of the fibula at a somewhat higher level. The iliotibial band inserts into it.

The prominent *medial condyle of the femur* can be felt on the medial side of the knee. Above and deeply placed, the *adductor tubercle* marks the lower point of insertion of the adductor magnus tendon into the femur. This is an accurate guide to the distal epiphysial line, which runs horizontally just above the trochlear surface of the femur. Behind the medial epicondyle, the *sartorius muscle* and *gracilis tendon* curve about the medial aspect of the condyle, and then incline almost directly forward and insert into the upper and medial aspect of the tibial shaft. At the knee these tendons are related closely to those of the semimembranosus and semitendinosus muscles.

In active extension of the leg the tendon of the *rectus femoris muscle* forms a tense band which is inserted into the proximal border of the patella. The *vastus medialis muscle* forms a prominent elevation on the medial side of the rectus tendon, and the vastus lateralis muscle, a similar bulge on the lateral side at a more proximal level. Disuse atrophy of the vastus muscles calls attention to more or less painful joint conditions with limited joint function. A very evident depression lies distal to the bulge formed by the lateral vastus muscle between the rectus femoris muscle medially and the iliotibial tract laterally. With the leg in relaxed extension, as in reclining, the whole quadriceps apparatus relaxes, the suprapatellar depression is deeper, the bulges of the vasti are less prominent, and the patella can be moved freely.

When the leg is flexed, the patella at first becomes more prominent, but as the move-

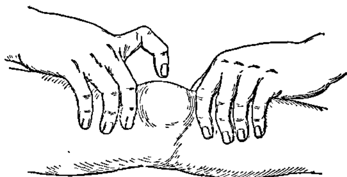


Fig. 944. ELICITING THE "TAP" OR "CLICK" OF THE FLOATING PATELLA IN SYNOVITIS OF THE KNEE. The hands are used to gather the fluid under the floated patella so that the index finger may percuss and elicit the "tap" or "click." (Moorhead.)

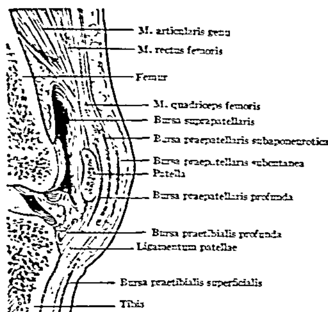


Fig. 945. SCHEMATIC SAGITTAL SECTION THROUGH THE KNEE REGION TO SHOW THE POTENTIAL DIVISION OF THE PREPATELLAR BURSA AND THE BURSA OVER THE TIBIAL TUBEROSITY.

ment is continued, it sinks deeply into the hollow of the intercondyloid notch and becomes firmly fixed, the apex corresponding to the joint line. Through the thin layer of tissue above the patella the upper part of the trochlear surface of the femur may be felt. In flexion the interval between the tibia and femur anteriorly is increased; the condyles of the femur become more distinct, and their curved lower margins are defined more readily. In the kneeling position the patella protects the joint and, with the tuberosity of the tibia, supports the superincumbent and semitendinosus weight.

SUPERFICIAL STRUCTURES AND DEEP FASCIA. The *skin* over the anterior region of the knee is moderately thin and has a high degree of mobility. It is very resistant, as is the lamellated layer of *superficial fascia*.

The superficial structure of surgical interest is the PREPATELLAR BURSA, which lies between the skin and the front of the lower part of the patella and patellar ligament (Fig. 945). A division of it may be found between the deep fascia and the tendinous covering of the patella or even beneath the tendinous coverings of the patella itself. As a rule, the interior of the bursal space is intersected by fibrous bands. This large bursa allows the skin to glide over the patella and withstand pressure. It especially adapts the patella for use in the Gritti-Stokes amputation through the knee (p. 1001).

This bursa, because of its superficial and exposed position, becomes inflamed easily. Effusion may occur within it and terminate in suppuration—*acute, suppurative prepatellar bursitis* (Fig. 946). This acute septic bursitis requires prompt drainage by incision on each side of the median line. Failure to institute drainage may result in escape of the purulent contents of the bursa into the loose subcutaneous tissue about the knee. This diffusion gives rise to a swelling which has the appearance of a knee-joint effusion, but the abscess always is superficial rather than deep to the patella.

If the inflammation follows a chronic course, the bursa usually becomes distended with clear serous fluid which forms a soft fluctuant swelling anterior to the knee. This condition, commonly known as "housemaid's knee," occurs from the irritation caused by frequent and prolonged kneeling on a hard surface. Chronic bursitis requires complete excision of the bursa. A curved incision with upward convexity is made through the superficial tissues at the upper part of the swelling. The superficial tissues are raised from contact with the cystic swelling, which is then dissected completely from the patella and its ligaments. The scar from an incision with the convexity downward sometimes is a source of pain or tenderness from pressure in kneeling.

In those whose occupation requires constant kneeling, a small, subcutaneous PRETIBIAL BURSA is sometimes present in front of the tibial tuberosity and the distal part of

the patellar ligament. A bursa related to the deep surfaces of the tendons at the medial aspect of the knee occasionally is enlarged, and forms an ovoid swelling at the medial aspect of the tibia and the tibial collateral (internal lateral) ligament of the knee joint.

The deep aspect of the ENVELOPING FASCIA of the knee is intimately adherent to the subjacent tendinous structures. Laterally, the fascia is adherent to tendinous fibers of insertion of the iliotibial tract. It is attached mesially to the condyle of the tibia, and, inferior to this, is fused to the expanding terminal tendon of the sartorius muscle.

QUADRICEPS EXTENSION APPARATUS. The musculotendinous suprapatellar segment, the patellar segment and the patellar tendon are the divisions of the quadriceps femoris extension apparatus which properly belong to the knee region.

The *suprapatellar segment* has the combined strength of its four component muscles, which is exerted through their tendons of insertion into the base and borders of the patella (Figs. 904, 931). The direction of the pull on the patella is not in a straight line along the thigh, but along the most direct course to the insertion into the tibial tuberosity. Hence contraction of the quadriceps muscle tends to dislocate the patella laterally out of the trochlear groove (p. 1029).



Fig. 946. PREPATELLAR BURSITIS (HOUSEMAID'S KNEE).
(Binnie.)

The rectus femoris muscle is inserted in the median line into the anterior border of the base of the patella by a thin layer, and most of its fibers continue over the bony surface to form the infrapatellar ligament. The fibrotendinous layer is attached to the rough longitudinal striae of the patella. On each side of the rectus femoris tendon are the prominent muscle bulges and short common tendons of the medial and lateral vasti. These muscles are inserted mainly into the base of the patella posterior to the flattened attachment of the rectus femoris muscle and to the lateral and mesial margins of the bone in its upper third. In the median line, deep to the tendon of the rectus femoris, is the vastus intermedius (crureus) muscle, which is inserted more posteriorly into the base of the patella. The suprapatellar arrangement clasping the upper third of the patella is in three superimposed layers: a superficial layer, formed by the tendon of the rectus femoris; a middle layer, consisting of the tendons of the vasti; and a deep layer, made of the tendon of the vastus intermedius. The insertions of this suprapatellar complex at different levels explain the rupture of one or more of the components of the quadriceps extension apparatus.

The *patella*, or bony part of the quadriceps apparatus, is a true sesamoid bone. Part of the suprapatellar structures pass over and by it to form the *infrapatellar ligament*, which fixes the patella in definite relation to the tibia.

Fibrotendinous (*quadriceps*) *expansions* (Fig. 931) from the inferior margins of the vastus muscles crisscross over the anterior surface of the patella, superficial to the patellar fibers of the rectus femoris muscle. These expansions diverge on each side and anchor the quadriceps muscle and the patella to the enveloping fascia, making for stability of the patella, and reinforcing the capsule of the knee joint.

The *lateral and mesial retinacula* (*accessory patellar ligaments*) are strong, resistant, fibrous supports connecting the margins of the patella near its apex with the margins of the tibial plateaus and the anterolateral surfaces of the tibial condyles as far back as the collateral ligaments (Fig. 947). Their purpose is to fix the apex of the patella to prevent dislocation, which can occur only after these supports have been stretched and lacerated. The stronger and more expansive mesial retinaculum overcomes the tendency to lateral displacement.

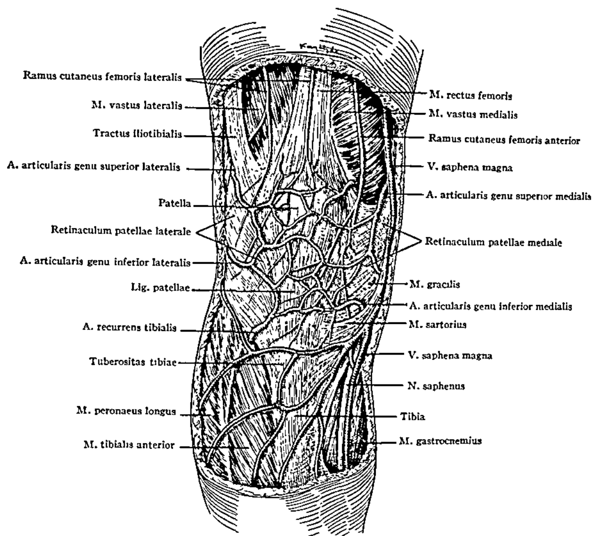


Fig. 947. VASCULONEURAL AND APONEUROTIC ELEMENTS IN THE ANTEROLATERAL REGION OF THE KNEE.

VESSELS. The *arteries* of this region are branches from the popliteal, the supreme geniculate (anastomotica magna), femoral (descending branch of the lateral femoral circumflex), and the recurrent branch of the anterior tibial (Fig. 947). Their terminals in the subcutaneous tissue form a rich network over the bones, ligaments and tendons, known as the articular rete of the knee. This network is arranged in three well defined arterial arches on the anterior aspect of the joint. The uppermost of these arches lies in the midst of the superficial fibers of the quadriceps muscle near the upper border of the patella. The two lower arches are directed transversely through the fatty tissue behind the patellar ligament. After ligation of the popliteal artery the circulation in the leg is maintained through these collateral anastomoses. The *lymphatics* follow the course of the great saphenous vein and drain into the inguinal nodes.

Surgical Considerations

DISLOCATION OF THE PATELLA. Acute traumatic displacement of the patella is uncommon; it is opposed by the normally prominent outer lip of the trochlea of the femur and by the strong medial tendinous expansion of the vastus medialis muscle and the medial patellar retinaculum. Displacement almost always is lateral (Fig. 948); it may be caused by direct violence or by exaggerated muscle action with the leg in extension. In that position, and even in moderate flexion, the patella stands out prominently, and the tendinous expansions of the vasti are relaxed. If the lateral femoral condyle is underdeveloped, or if there is considerable "knock knee," there is a predisposition to dislocation, which, having occurred once, tends to recur. Occasionally, with direct violence, the patella undergoes a rotary displacement and is twisted around through a right angle, with the result that one of its lateral

margins lies in contact with the groove of the trochlea, while the other is directed forward. Reduction can be effected only after complete relaxation of the quadriceps muscle.

A satisfactory *operative treatment* for recurrent dislocation consists in transplanting the outer half of the patellar ligament under the mesial half, and suturing it to the periosteum and sartorius expansion over the medial condyle of the tibia (Goldthwaite). This is especially useful in children before the upper tibial epiphysis, of which the tibial tubercle is a part, is closed. More satisfactory in an adult, after the epiphysial plate of the upper tibia has closed, is the downward and medial transference of the tibial tubercle with the insertion of the infrapatellar tendon. This procedure shifts the pull of the quadriceps muscle medially, and the shortening of the tendon holds the lateral margin of the patella against the lateral femoral condyle.

In an adult frequent recurrent dislocations of the patella will result in arthritic changes, causing a chondromalacia of the articular surface of the patella. Frequently there is also found some roughening of the opposing surface of the lateral femoral condyle which causes pain, crepitation and effusion of the knee. Because of this, if a chondromalacia of the patella is found in the surgical exposure of the knee in an adult, it is wise to do a total patellectomy rather than attempt other surgical procedures as previously discussed, such as transference of the tibial tubercle medially and inferiorly.

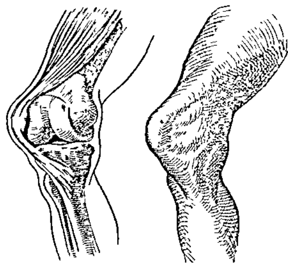


Fig. 948. LATERAL DISLOCATION OF THE PATELLA. (Hoffa.)



Fig. 949. STELLATE FRACTURE OF THE PATELLA FROM DIRECT VIOLENCE.

Since the tendinous expansions are not torn, there is no separation of the fragments. (From Babcock: Textbook of Surgery.)

FRACTURE OF THE PATELLA. The connections and relations of the patella reveal its disadvantageous position as regards exposure to trauma. It is interposed as a shield between the knee joint and the exterior, and is suspended between the quadriceps muscle and the patellar tendon, where it undergoes great longitudinal strain.

Two types of injury to the patella are recognized according to the kind of violence which causes them. The patella is exposed to *direct violence* from falls or severe blows upon the knee (Figs. 949, 950). In a fall the principal impact is borne by the tuberosity of the tibia. Fractures of the patella so produced usually are comminuted in a stellate fashion, but the tendinous expansions of the vasti generally remain untorn, so that there is, as a rule, little separation of the fragments.

Fractures from *indirect violence* usually are caused by pure muscle contraction, and commonly by attempted extension with the leg in flexion, as in forcible muscle effort to prevent falling backward. When the quadriceps muscle undergoes a sudden contraction with simultaneously increased flexion at the knee, a great strain is thrown upon the patella. The base of the patella is held against the femoral condyles, which act as a fulcrum, and the unsupported distal portion is drawn backward by forced flexion of the leg. Not only is the patella fractured transversely, but also the tendinous expansions of the vasti are torn widely (Fig. 950). The usual fracture of the patella opens into the joint, which soon fills with blood. The distal or apical extremity of the bone is not of necessity intra-articular, since it is separated from the joint by some fatty tissue and a layer of synovial membrane. Patellar fracture

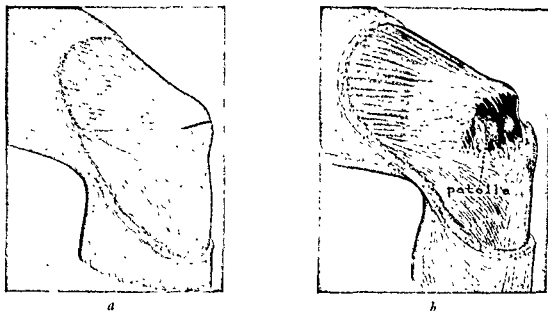


Fig. 950. TRANSVERSE FRACTURE OF THE PATELLA BY DIRECT VIOLENCE.

a, In this case there is slight separation of the fragments, because the lateral tendinous expansions have not been ruptured. *b*, As a result of extensive tearing of the tendinous supports, marked separation of the fragments occurs.

ordinarily results in separation of the fragments, the edges of which are covered by frayed fibers of the quadriceps tendon. The intervening gap may be slight, but may amount to 5 cm. or more. Its extent depends upon the traction exerted by the quadriceps muscle upon the proximal fragment, and is influenced largely by the degree of tearing of the tendinous expansions of the vasti muscles.

A patellar fracture in which the lateral capsular reinforcements are torn is immediately disabling, for, although the weight can be balanced upon the passively extended foot, no active movement can be made in extension.

Fractures resulting from indirect violence, in which there is definite separation of the fragments, demand early *operative treatment.* A horseshoe-shaped flap, with its convexity upward, is raised from the front of the joint, and the site of the fracture is exposed fully. The joint cavity is emptied of blood clots, any soft tissue interposed between the bony fragments is removed, and the fractured surfaces are brought into close and accurate apposition by stitches taken through the covering of the bone or through drill holes in the bone. The lateral tears in the tendinous expansions must be sutured carefully, or much of the advantage of the operation is lost. A snug suture of the lateral expansions usually holds the patellar fragments in apposition without sutures through the bone. Unless the tendinous fringes which have dropped between the fracture fragments are removed before the fragments are approximated, the bony surfaces cannot be brought into immediate contact, and the union is fibrous, especially since the patella is a sesamoid bone without periosteum, and bone repair can take place only from the fractured surfaces.

It is advisable to excise the distal fragment if it is small or comminuted, and suture the infrapatellar tendon to the main proximal fragment. If the entire patella is comminuted, all fragments should be removed.

Conservative treatment should be reserved only for those cases in which separation of the fragments has not occurred. In conservative treatment the leg is elevated in extension to relax the quadriceps, and the thigh is flexed at the hip to relax the rectus femoris still further. Fibrous if not actual bony union, with slight degrees of separation of the fragments, may be expected if there is no obvious tearing of the expansions of the quadriceps.

Suprapatellar and Infrapatellar Rupture of the Quadriceps Muscle. The pull exerted by the longitudinal strain of quadriceps muscle contraction may cause, instead of fracture of the patella, a rupture of the suprapatellar portion of the muscle or of the patellar ligament, or a tearing away of the tibial insertion of the tendon.

Any or all of the suprapatellar divisions

of the quadriceps, which insert at different levels into the base and margins of the bone, may rupture close to their attachments. The adjacent capsule may be torn and the joint be exposed. If normal function is to be restored, the gap must be repaired by accurate suturing of the lacerated structures. Rupture of the patellar tendon by muscle action is rare.

Avulsion of the tibial tuberosity occurs in youth before the epiphysis of the tibial tubercle is ossified, and usually is caused by excessive muscle strain from the quadriceps. Minor degrees of the accident cause loosening and partial separation of the tubercle. The condition becomes chronic if untreated; extension of the leg can no longer be performed fully, and soreness, lameness and swelling develop. To rest the quadriceps muscle and permit the tubercle to become fixed firmly, the knee must be immobilized. In the less severe cases, in which only slight separation of the epiphysis occurs, adhesive strapping limits extension and steadies the tuberosity until healing takes place.

Osgood-Schlatter's disease is an epiphysitis (osteochondritis) of the tibial tuberosity. The condition is analogous to deforming osteochondritis of the hip (Legg-Perthes' disease) and to epiphysitis of the tarsal scaphoid (Köhler's disease). Roentgenograms show the bony epiphysis to be altered in shape, fragmented, and without the normal trabeculation. Views of both tuberosities may be required to differentiate this condition from avulsion of the normal tibial tuberosity. Epiphysitis of the *tibial tuberosity frequently is bilateral.*

Treatment of this condition is symptomatic, which may require merely the protection against direct contusion of the tibial tubercle, avoiding as much as possible stair climbing and kneeling; occasionally the use of a protective bandage to the knee or a cylinder cast for six to eight weeks may be necessary. There is no indication for surgical treatment in the acute stage. In the adult, if the condition has resulted in a marked prominence of the tibial tubercle which becomes traumatized with direct contact, surgical removal of the prominence may be indicated.

Posterior or Popliteal Region

The posterior aspect of the knee coincides with the region known as the popliteal space. This space, with an osteofibrous floor, rigid musculotendinous walls and a strong posterior aponeurosis, affords a protected passage for the neurovascular trunks passing from the thigh to the leg. As a flexor area, it occupies the same sheltered position as the analogous flexor region of the elbow.

Boundaries and Divisions of the Popliteal Fossa. The muscles which bound the popliteal fossa laterally, circumscribe a lozenge-shaped space consisting of an upper, or femoral, and a lower, or tibial, triangle (Fig. 951). The lateral boundaries of the femoral triangle are recognized easily through their superficial coverings. The *lateral wall* consists of the combined long and short heads of the biceps muscle. A septum of the overlying deep fascia is applied to the mesial surface of the biceps, binding it down to the lateral lip of the linea aspera of the femur. The strong rounded tendon of the biceps passes slightly posterior to the lateral condyle of the femur, and divides to surround the fibular attachment of the fibular collateral (external lateral) ligament. The *mesial wall* of the upper triangle is composed of a complex of four muscles: the semitendinosus, semimembranosus, sartorius and gracilis. These are held together in a common bundle by a septum of deep fascia which binds this bundle down to the mesial lip of the linea aspera. Through an interval in this septum, which is directly continuous with the adductor ring in the adductor magnus tendon, the neurovascular trunks of the thigh enter the popliteal space. The semimembranosus forms the bulk of this mesial mass of muscles, and its tendon passes behind the medial condyle of the femur and inserts into the medial condyle of the tibia. The posterior surface of the semimembranosus is grooved by the tendon of the semitendinosus, which is the prominent palpable tendon in this wall. The tendons of the gracilis and sartorius pass forward more anteriorly to insert into the medial surface of the tibia.

The lower or tibial triangle, which is much smaller, has its lateral boundaries formed by the two heads of the gastrocnemius muscle, which, in turn, is embraced by the muscles forming the lateral boundaries of the femoral triangle. The space within the triangle is narrow, so that the two heads of the gastrocnemius not only form the two lateral boundaries, but also, to a large extent, cover the posterior aspect of the joint. The origin of the

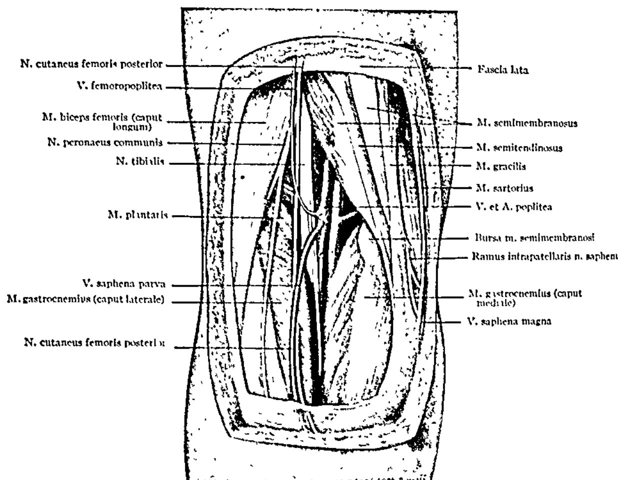


Fig. 951. LEFT POPLITEAL SPACE AND ITS CONTENTS.
The roof of investing fascia has been removed.

soleus muscle is at the apex of this triangle. Through the tendinous arch of the soleus the popliteal vessels enter the calf of the leg. This pathway allows the reciprocal spread of infection between these adjoining regions.

The *roof* of the two triangles forming the popliteal space is a thin, strong sheet of deep fascia which is pierced near its center by the small saphenous vein. The *floor* of the space is the popliteal surface of the femur, enclosed between the diverging lines of bifurcation of the linea aspera (Figs. 951, 952). The lower part of the floor is the posterior surface of the posterior ligament of the knee joint with the related posterior part of the joint capsule. This is overlaid by the *popliteus muscle*, which arises within the capsule of the knee joint from the lateral femoral condyle. The muscle passes distally and medially across the back of the knee joint and inserts into the proximal part of the posterior surface of the tibia. Near its origin the popliteus is surrounded by a bursa lying between the lateral meniscus (semilunar cartilage) and the fibular collateral ligament The popliteus muscle is a flexor of the leg, but acts as a medial rotator of the tibia when the knee is flexed. It is supplied by the tibial (internal popliteal) nerve (L 4, 5; S 1).

The resistant fascia roofing the fossa unites with the tendons and muscles forming the walls of the space and covers a well delimited cavity, incapable of great distention. If the cavity contains a purulent collection, a cyst, a hernia of the capsule or a popliteal aneurysm, pressure is exerted on the nerves, causing intense pain.

LANDMARKS. When the *knee is extended*, the muscles forming the lateral boundaries of the space and the deep fascia by which it is covered are rendered tense, and the cutaneous surface appears full and slightly rounded from side to side. Because of the unyielding character of the tissues, it is not possible to make out any details of the space and its contents. A proximal relief or bulge, representing the neurovascular structures, occupies the long axis of the space

Extension places the contents of the space on tension and is the position which most favors operative procedures.

When the *knee is flexed*, the muscle boundaries and deep fascia of the part are relaxed, and the popliteal space can be palpated as a vertical median furrow extending from the lower part of the thigh downward beyond the knee joint line. The semitendinosus tendon on the mesial aspect and the biceps tendon on the lateral aspect are unmistakable landmarks. On deep palpation the fingers slip into the upper part of the space and identify the triangular interval on the back of the femur and the popliteal vessels and tibial (internal popliteal) nerve. The popliteal artery, which runs close to the bone, can be palpated and compressed easily, and is damaged readily in fracture of this part of the femur (p. 993). The common peroneal (external popliteal) nerve is distinctly palpable first under cover of, and then posterior to, the biceps tendon before the nerve winds about the head of the fibula to enter the peroneal or lateral compartment of the leg (p. 1044).

Popliteal Bursae. The extensive play of the muscles and tendons about the knee demands their protection by multiple bursae (Fig. 953); the role of these bursae in knee injuries justifies their enumeration. As a group, they are subject to irritation from undue strain and overexercise and must be considered a cause of disability in this region.

Of the *posteromedial bursae*, the semimembranosus bursa, which lies on the medial head of the gastrocnemius muscle, is most extensive; it reaches the joint line and often communicates with the joint cavity. The bursa for the medial head of the gastrocnemius muscle facilitates play of the capsule over the medial femoral condyle. It often is in communication with the semimembranosus bursa and with the joint. Bursae separate the tendons of the sartorius, gracilis and semitendinosus from each other at their insertions and from the tibial collateral (internal lateral) ligament.

The *posterolateral bursae* are related to the important structures playing across the joint line and to the outer bony prominences, the biceps tendon, the fibular collateral (external lateral) ligament, and the popliteus and gastrocnemius muscles. The bursa of the biceps lies on the head of the fibula deep to the tendon and, when swollen, simulates enlargement of the fibular head. Another biceps bursa is interposed between the tendon of that muscle and the fibular collateral ligament. The bursa for the popliteus muscle regularly com-

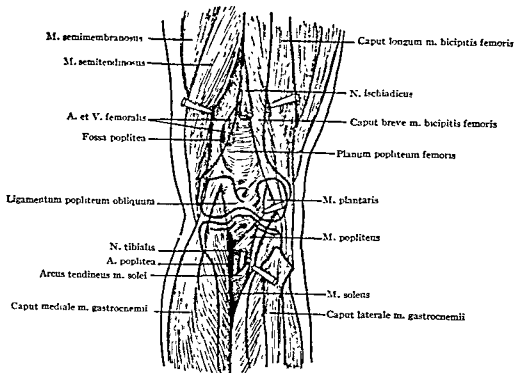


Fig. 952. FLOOR OF THE RIGHT POPLITEAL SPACE.
The lateral walls of the fossa are retracted, and the vasculoneural contents of the space are removed. (After Corning.)

Fig. 953. IMPORTANT BURSAE ABOUT THE RIGHT POPLITEAL SPACE.

municates with the joint (p. 1025). The origin of the popliteus from the lateral femoral condyle is intracapsular, and winds obliquely downward and behind the joint line and lateral meniscus. The popliteal bursa, which sometimes is a tubal extension of the knee-joint synovia, extends downward and outward beneath the popliteal muscle. A diverticulum of synovia lies between the tendon and the lateral meniscus, so that the meniscus has little attachment to the tendon and capsule. This arrangement allows the meniscus free movement on the tibia, a fact which probably accounts for its relative freedom from injury. The inferior diverticulum of the bursa often communicates with the superior tibiofibular joint. A bursa is situated between the lateral head of the gastrocnemius and the capsule covering the lateral femoral condyle; it sometimes communicates with the knee joint.

Infrequently, small *posterior synovial diverticula* herniate through the fibers of the oblique posterior ligament of the knee joint.

Popliteal Artery and Veins. The popliteal artery enters the superior and medial part of the popliteal space through the tendinous arch in the adductor magnus muscle (Fig. 951); it is a continuation of the femoral artery. As the popliteal artery passes through the popliteal space, it inclines laterally along the outer border of the semitendinosus muscle until it reaches the middle of the limb; it then descends vertically to the distal border of the popliteal muscle and terminates by dividing into the anterior and posterior tibial arteries. It lies at first along the lateral border of the semimembranosus muscle, but gradually inclines laterally and gains the midline of the limb at the level of the intercondyloid notch of the femur and occupies a median position for the remainder of the course. The popliteal artery throughout its course is placed deeply and lies in direct contact with the posterior ligament of the knee joint.

Three pairs of branches are given off by the popliteal artery at three different levels and are distributed mainly about the bony part of the knee. The *superior genicular arteries*, lateral and medial, originate at the level of the femoral condyles and wind about the femur proximal to the condyles. They are in close contact with the bone and anastomose with each other anteriorly. They anastomose also with the inferior genicular arteries, the descending branch of the lateral circumflex artery, and the articular branch of the superior geniculate (anastomotica magna) artery. The last anastomosis establishes circulation in the leg after ligation of the popliteal artery in its proximal portion.

The *middle genicular arteries* enter the knee joint through the posterior ligament. They are chiefly muscular and articular, and are distributed to the gastrocnemii and the structures within [illegible] *inferior genicular arteries*, late[illegible]

front of the knee, pass under cover of the tibial and fibular collateral (internal and external lateral) ligaments, and anastomose with each other deep to the patellar ligament. By communicating with the superior genicular arteries they contribute to the important anastomoses about the knee (Fig. 954). No branches are given off in the upper course of the popliteal artery; in this portion the artery is accessible for ligation. Should obstruction occur in the branches, the circulation is carried on through the intact collateral path; but if the obstruction is low and is close to the openings of all the important genicular arteries, collateral circulation is interfered with, and the possibility of gangrene impends.

The anterior and posterior tibial veins unite to form the POPLITEAL VEIN in the lower part of the space. The popliteal vein lies superficial to the artery, mesial to it distally, and lateral to it proximally. The SMALL SAPHENOUS VEIN, which runs over the calf of the leg on the enveloping fascia, pierces the deep fascia in the lower part of the popliteal space and divides into two branches, one entering the popliteal vein and the other the great saphenous vein. The popliteal vein and artery are bound wall to wall in a resistant connective tissue sheath, a relationship which explains their simultaneous injury and the formation of an arteriovenous fistula.

TIBIAL (INTERNAL POPLITEAL) NERVE. The tibial and common peroneal nerves are the terminal branches of the sciatic nerve at the upper angle of the popliteal space (Fig. 951). The tibial (internal popliteal) nerve (L 4, 5; S 1, 2, 3) continues the direction of the popliteal nerve and runs a straight course to the lower angle of the space superficial to the popliteal vessels, just beneath the deep fascia. As the vessels pursue an oblique lateral course, the nerve lies at first to their lateral side. Opposite the intercondyloid notch of the femur, the nerve lies immediately over both vessels,

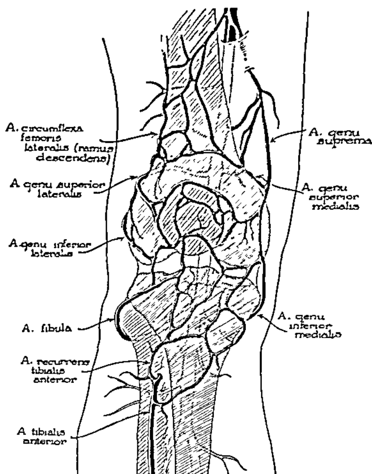


Fig. 954. COLLATERAL CIRCULATION ABOUT THE KNEE.

(After M. Reid: Am. J. Surg.)

and at the lower angle of the space, to their medial side. At the distal border of the popliteus muscle the tibial nerve passes deep to the soleus muscle and enters the posterior compartment of the leg.

While traversing the popliteal fossa, the tibial nerve distributes muscular, cutaneous and articular branches. The *muscular branches* supply both heads of the gastrocnemius muscle and the plantaris, popliteus and soleus muscles. The *cutaneous branch* or medial cutaneous nerve of the calf (ramus communicans tibialis) descends along the back of the leg and pierces the deep fascia in its middle third. It is joined by a corresponding branch of the common peroneal (external popliteal) nerve and the peroneal anastomotic (ramus communicans fibularis) nerve. The last two branches form the sural (external saphenous) nerve (S 1, 2). Three small *articular branches* supply the knee joint. The intimate relations between the popliteal vessels and the tibial nerve and its branches explain the nerve involvement in popliteal aneurysm.

Common Peroneal (External Popliteal) Nerve. The common peroneal (external popliteal) nerve (L 4, 5; S 1, 2) passes distally and laterally in close relation to the medial aspect of the biceps tendon, which forms the outer boundary of the femoral subdivision of the space (Fig. 951). It accompanies the biceps tendon to its insertion, and leaves the popliteal fossa between that tendon and the lateral head of the gastrocnemius muscle. The relation of this nerve to the biceps at its insertion must be borne in mind in biceps tenotomy for knee joint contracture (p. 1017). From this region the nerve descends behind the head of the fibula just beneath the deep fascia and winds around the lateral aspect of the fibular neck, piercing the origin of the peroneus longus muscle. The nerve ends by dividing into the superficial (musculocutaneous) and deep peroneal (anterior tibial) nerves.

The common peroneal nerve gives off no muscle branches, but supplies small articular twigs to the knee joint.

Popliteal Lymph Nodes. The popliteal lymph nodes form a superficial and a deep group. The superficial nodes surround the small saphenous vein where it pierces the deep fascia. Their afferent branches drain the lateral aspect of the leg and the foot, and their efferents drain to the deep group of popliteal glands.

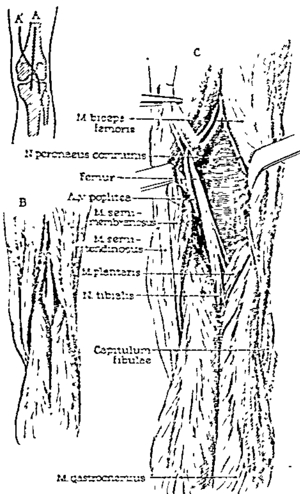


Fig. 955. POSTERIOR APPROACH TO THE LOWER END OF THE FEMUR AND POPLITEAL SPACE.

A, Straight midline popliteal incision is begun 3 inches above the knee joint and extended downward to about 1 inch below the joint. *A'*, A curved incision may be preferred because it minimizes the risk of postoperative contracture. *B*, The popliteal space is entered and its vessels and nerves identified. *C*, Careful medial retraction of the popliteal vessels, tibial nerve and medial muscles and lateral retraction of the common peroneal nerve and lateral muscles provide good exposure of the condylar portions of the femur and posterior articular capsule of the knee joint.

The deep lymph nodes lie in the fatty tissue about the popliteal vessels. Their afferents proceed from the deep tissues of the calf and sole of the foot and receive the efferents from the superficial glands. Many of the efferents from the calf and sole of the foot drain directly into the deep subinguinal nodes.

Surgical Considerations

Posterior Approach to the Lower End of the Femur and the Popliteal Space. This approach (Fig. 955) should be reserved for tumors and intrinsic pathologic conditions

that cannot be exposed by a medial or posterolateral incision. The inherent dangers are injury to the major vessels and nerves of the leg. In this type of incision, in which large nerves and vessels are being retracted without adequate protection by muscle bellies, careful retraction is necessary to prevent dangerous trauma to the nerves and vessels. The lateral edge of a retractor can quickly cause a pressure paralysis of a nerve, or trauma and thrombosis in a major vessel.

Popliteal Abscesses. After infection of the leg or foot, popliteal abscesses may arise in the popliteal lymph nodes and, because of their depth, are difficult to detect at an early stage. The infection is unusually painful because of the unyielding character of the walls of the fossa. For the same reason, and because of the fatty areolar tissue in which they are embedded, these abscesses are slow to heal when drained.

The next most frequent source of popliteal abscess is acute suppurative osteomyelitis of the lower end of the femur. Popliteal abscess may occur as a sequel to suppuration within the knee joint. The space may be invaded by way of the communicating popliteal bursae. Because of the dense and unyielding character of the deep fascia roofing the space, pus may remain unnoticed until the tissues of the space have become extensively infiltrated and the space has been converted into a large abscess cavity, within which the popliteal vessels and nerve lie free. Rarely the pus may burrow upward into the thigh through the ring in the adductor magnus muscle. Eventually the coverings of the space are eroded by ulceration, allowing the abscess to point. Not infrequently, thigh amputation must be performed because of intractable suppuration in the space from femoral osteomyelitis.

Incision for popliteal abscess is made best from the lateral aspect of the space anterior to the biceps tendon. When the deep fascia is divided, a hemostat is passed between the biceps tendon and the femur, and the pus is evacuated without injury to the large vessels and nerves.

Popliteal Aneurysm. The incidence of popliteal aneurysm approaches that of aneurysm of the thoracic aorta. The longitudinal strain thrown upon a normal artery during extension of the leg produces no untoward effect, but may rupture the coats of a diseased vessel and result in the development of an aneurysm. Popliteal aneurysm (Fig. 956) enlarges rapidly because of its location in the midst of loose tissue and because of the absence of the muscle support common to the other vascular trunks of the extremity. The obliquely curved course of the popliteal artery distributes pressure irregularly in the artery, and the bifurcation tends to increase the tension in the main trunk.

If aneurysm develops proximal to the joint line, only a few of the collateral branches entering into the anastomosis about the knee are involved. If aneurysm develops distal to the joint line, it involves the mouths of the more numerous collateral branches which present there, introducing the danger of gangrene. The presence of aneurysm may be accompanied by stiffness and pain in the knee, not unlike that of chronic arthritis. The leg is maintained in the semiflexed position and can be straightened only with difficulty. When aneurysm develops toward the superficial aspect of the space, its progress usually is rapid, since it meets with little resistance. Pressure on the nerves produces great pain and muscle weakness. When aneurysm develops toward the deep aspect of the space, it may erode the bones and the joint.

Rupture of a popliteal aneurysm almost certainly leads to gangrene of the leg, since the venous return and, eventually, the arterial flow of the leg are interrupted by the pressure within the space. A pulsatile swelling within the space is not necessarily an aneurysm, inasmuch as cystic or other tumors in the vicinity may transmit the pulsations of the popliteal artery.

Injury to the Popliteal Artery. This is a serious affair, it being recorded that gangrene results in from 45 to 100 per cent of cases when the vessel is ligated immediately, and vascular insufficiency is a common sequel when the limb survives. When the artery is damaged and a pulsating hematoma results which expands or bleeds subsequently, or when circumstances dictate ligation a few days after injury, gangrene is less likely to occur. If a false aneurysm develops and the artery is ligated some months later, the danger of gangrene is remote.

Approach to the Popliteal Artery. This is generally carried out through a more or less standard posterior (Fig. 957) or medial (Fig.

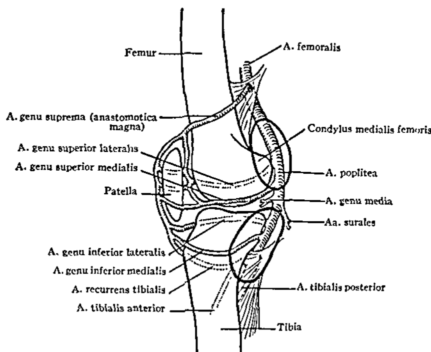


Fig. 956. EFFECT OF ANEURYSM UPON THE ANASTOMOSING CHANNELS WITHIN AND ABOUT THE POPLITEAL SPACE.

The upper circle indicates the location of an aneurysm in the upper portion of the popliteal artery. Since it obliterates only a few branches, an efficient collateral circulation can be established. The lower circle indicates an aneurysm in the lower part of the popliteal artery, where branches are numerous. The resulting tumor is a serious obstacle to collateral circulation and may cause gangrene of the leg. (Modified after Testut and Jacob.)

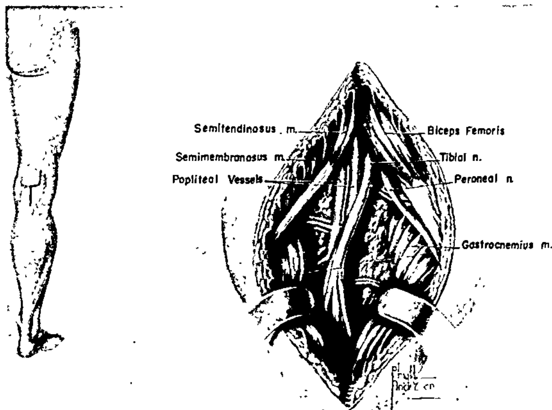


Fig. 957. POSTERIOR APPROACH TO THE POPLITEAL VESSELS.
(From Seeley, Hughes and Jahnke, Jr.: Ann. Surg., 138: 712-17, 1953.)

958) incision. Seeley, Hughes and Jahnke, Jr.,* used them successfully in handling twenty-six lesions of the popliteal artery, of which ten were false aneurysms and sixteen were arteriovenous fistulas. Excision of such lesions with end-to-end anastomosis was the treatment of choice. Up to 1 inch of the popliteal vessel can usually be excised and the ends brought together after freeing the artery for 2 to 3 inches in each direction. With larger defects an arterial bank graft or fresh autogenous vein graft is required, usually using a portion of the saphenous vein. Whenever possible, the popliteal vein is preserved in order to avoid venous insufficiency.

Popliteal Cysts. The cystic tumors commonly found in the popliteal space arise from the popliteal bursae and projections of synovial membrane from the knee joint. The bursa between the medial head of the gastrocnemius muscle and the posterior ligament of the knee joint is irritated frequently, may attain a considerable size, and may form a fluctuant swelling at the back of the knee. The cyst outline usually may be determined readily with the leg in flexion. When cysts communicate with the knee joint synovia, it sometimes is possible to diminish their volume by continued pressure, reduction of the mass being dependent upon the kind of fluid contained and the size of the aperture into the knee joint. Popliteal pulsation may be transmitted to these swellings, but the pulsation is not expansile. A large cyst is a source of inconvenience in movements of the knee and may require operative removal. Excision is most satisfactory through an approach over the most prominent part of the swelling.

Flexion Contractures at the Knee. Contracture of the posterior soft parts of the knee, with resulting flexion deformity, is common when flexion is maintained over a considerable period of time. The fact that the main origin of the hamstring muscles is on the pelvis, that the insertion is on the tibia, and that there is only a negligible attachment to the femur over the intervening space favors the production of this deformity.

The stretching of the extensor muscles mili-

* Ann. Surg., 138: 712–17, 1953.

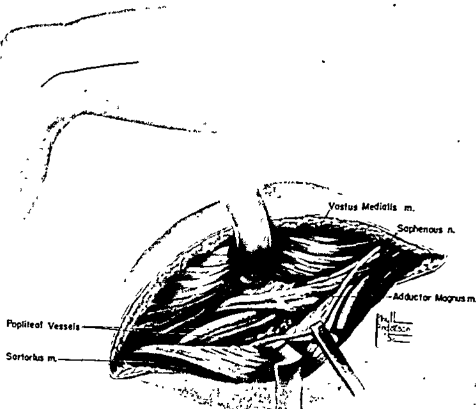


Fig. 958. MEDIAL APPROACH TO THE POPLITEAL VESSELS.

(From Seeley, Hughes and Jahnke, Jr.: Ann. Surg., 138: 712–17, 1953.)

tates against easy correction of the contracture. If the contracture is neglected, retraction of other structures about the joint occurs. The posterior joint capsule and popliteal artery are shortened to the degree that mechanical manipulation may do irreparable harm. A neglected flexion contracture, if associated with a chronic joint lesion, immobilizes the joint by fibrous and even bony ankylosis. Mobilization may be accomplished only by prolonged traction, tenotomy and posterior capsuloplasty.

The principal difficulty in *tenotomy of the hamstring tendons* is encountered in the division of the biceps tendon, since the common peroneal (external popliteal) nerve, which descends in close relation with the inner border of that tendon, may be injured. If the biceps muscle is made tense by applying an extending force to the leg, its tendon can be recognized readily. Free incision over the tendon with a full view of the operative field is preferable to subcutaneous tenotomy. Tenotomy should be performed from 3 to 4 cm. proximal to the tendon insertion on the head of the fibula. The division of the semitendinosus and semimembranosus tendons presents little difficulty, since no vital anatomical structures are endangered.

POSTERIOR CAPSULOPLASTY. Posterior capsuloplasty is performed to correct flexion deformity at the knee. The essential feature in the operation is lengthening of the posterior capsule of the knee by stripping away its superior attachment from the posterior surface of the femur. Lengthening of the biceps tendon is combined with capsuloplasty because the biceps muscle is responsible for much of the subluxation and lateral rotation of the tibia on the femur. The iliotibial band is divided because it definitely limits extension at the knee.

An incision 12 cm. long over the lateral aspect of the knee, and extending from just above the femoral condyle to the head of the fibula, exposes the iliotibial band and the biceps tendon. The iliotibial band is divided transversely at a level 5 cm. proximal to the joint interval. After retraction of the common peroneal (external popliteal) nerve the biceps tendon is isolated and freed as far as its insertion into the head of the fibula. The biceps tendon is lengthened by division with a Z-shaped incision. The lateral portion of the knee joint capsule is exposed. The capsule is incised at the posterior border of the articular margin of the lateral condyle of the femur, and the posterior compartment of the knee joint is opened. A periosteal elevator is introduced into the joint, and the posterior capsule is stripped upward subperiosteally from the back of the femur. Subperiosteal dissection is carried to the midline of the femur and upward 8 cm. from the joint line.

A second incision is made over the medial aspect of the knee from the adductor tubercle to slightly below the joint line. Incision of the capsule at the posterior margin of the joint opens the posterior compartment. The subperiosteal stripping of the posterior capsule is now performed from the medial side. The medial dissection, carried upward and laterally, meets the dissection from the lateral side. It usually is necessary to free subperiosteally the tight capsular structures which remain attached to the femur around the intercondyloid notch. The capsule is then closed. The extremities of the divided biceps tendon are sutured, and the leg can be extended and immobilized (Wilson).

LIGATION OF THE POPLITEAL ARTERY. Ligation of the popliteal artery may be performed for aneurysm or wounds of this vessel. The artery is reached most readily at the upper and medial part of the popliteal space (Figs. 959, 960). A medial popliteal incision is made parallel to and just behind the tendon of the adductor magnus. In dividing the superficial tissues and deep fascia, the great saphenous vein and the saphenous nerve are exposed. These structures and the sartorius muscle are retracted backward. The tendon of the adductor magnus is defined and drawn forward. Care is taken to avoid injury to the deep branch of the superior geniculate (anastomotica magna) artery. Upon displacing the semimembranosus muscle backward and deepening the interval between that muscle and the adductor magnus tendon, the popliteal artery, surrounded by loose fatty tissue, and the popliteal vein to its lateral side are found lying in close contact with the femur. The vasculoneural sheath is incised carefully on its medial aspect, and the popliteal and tibial veins, which lie posterolaterally, are avoided.

In the inferior part of this approach a cleavable interspace separates the gracilis tendon from the mesial head of the gastrocnemius muscle. By deepening this cleft, the gastrocnemius can be retracted from the popliteus muscle and the origin of the soleus muscle

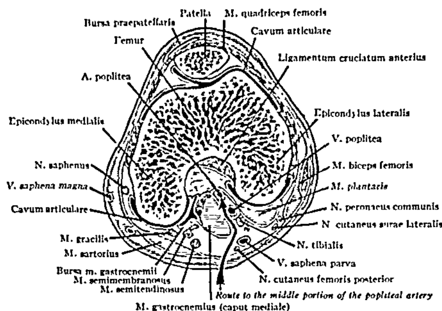


Fig. 959. TRANSVERSE SECTION THROUGH THE RIGHT KNEE, PASSING THROUGH THE FEMORAL CONDYLES, TO SHOW THE SURGICAL APPROACH TO THE POPLITEAL ARTERY IN THE MIDDLE OF ITS COURSE.

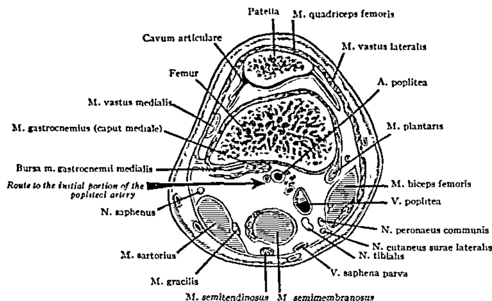


Fig. 960. TRANSVERSE SECTION THROUGH THE RIGHT KNEE IN THE UPPER PART OF THE POPLITEAL SPACE TO SHOW THE SURGICAL APPROACH TO THE INITIAL PART OF THE POPLITEAL ARTERY.

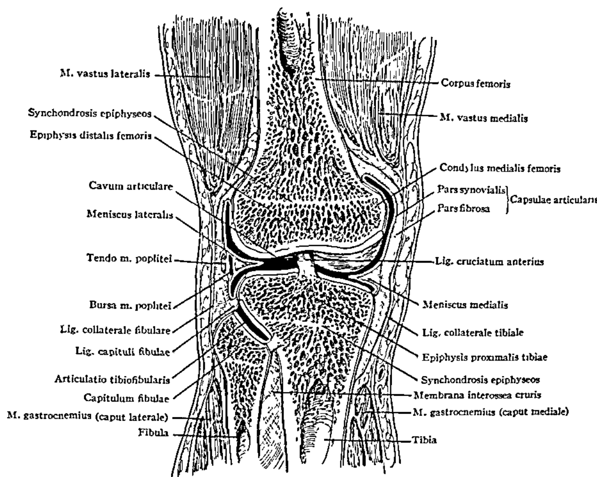


Fig. 961. SCHEMATIC FRONTAL SECTION THROUGH THE RIGHT KNEE JOINT.

which covers the bone. The popliteal artery may be ligated after it reaches the soleus hiatus and before it bifurcates into its two terminal branches. The combined incision affords adequate drainage for abscess in the space.

Bones and Joints

The skeletal structures of the knee include the lower extremity of the femur, the upper extremity of the tibia, the patella, and the head of the fibula (Fig. 961). These structures form the knee joint proper and the superior tibiofibular joint. The knee joint includes the articulation of the patella with the trochlea of the femur (Fig. 962).

LOWER EXTREMITY OF THE FEMUR. The lower extremity of the femur is expanded laterally into the two *condyles*, which are prominent articulating eminences, elongated anteroposteriorly and relatively narrow laterally. The condyles are adapted to anteroposterior rocking in the shallow concavities of the tibial head. The somewhat obliquely placed medial condyle is narrower and shorter anteroposteriorly than is the outer one. The articular surface of the lateral condyle is directed in a sagittal plane. When the shaft of the femur is vertical, the medial condyle extends farther downward than the lateral condyle; but when the shaft is inclined medially with its normal degree of obliquity, the plane of the lower surface of each condyle is almost horizontal. Both condyles are roughened medially and laterally for the attachment of ligaments, and are surmounted by *condylar ridges* which are readily palpable when the leg is flexed, but difficult to palpate when it is extended.

The cartilage-covered surfaces of the condyles are continuous in front and form the *trochlea*, a shallow depression for articulation with the patella when the leg is extended. The lateral surface of the trochlea is more prominent and ascends to a higher level than the medial surface. The portion of the femur immediately above the trochlea is perforated by large vascular foramina, and is covered by a layer of synovial membrane and a quan-

tity of subsynovial fat which supports the proximal two thirds of the patella when the leg is extended.

Nearer to the posterior than to the anterior part of each condyle is the irregular prominence of the *epicondyle* for the attachment of the collateral ligaments. Proximal to the medial epicondyle is the small, bony projection of the medial condyloid ridge, the *adductor tubercle*, or point of insertion for the tendon of the adductor magnus muscle. Below the lateral epicondyle is a depression marking the origin of the popliteus muscle and lodging its tendon.

The condyles are separated posteriorly by a deep fossa, the *intercondyloid notch*, within which the crucial ligaments are lodged and to the walls of which their upper extremities are attached. In the femur, as in long bones generally, the thick cortex of the shaft thins out into a shell of compact bone which embraces the cancellous structure of the condyles. The compact cortical bone is thickest over the *margins of the intercondyloid fossa to strengthen* the areas of attachment of the crucial ligaments. The condyles are so separated and weakened by the trochlear groove and the intercondyloid notch that lines of fracture often extend up the base of the fossa.

The lower extremity of the femur *develops* from a single center of ossification which appears in the cartilage during the ninth month of fetal life. The finding of this center in a stillborn infant has been accepted as proof that the fetus has come to term. In accordance with the general rule that the epiphyses ossifying early unite late, union of the distal femoral epiphysis with the diaphysis takes place in the twenty-first year. The distal *epiphysial line* is

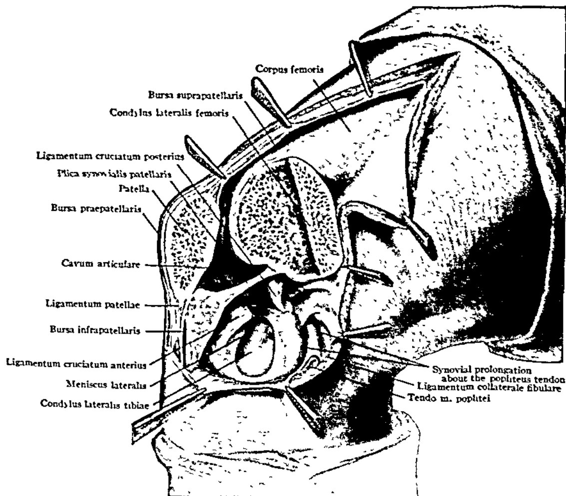


Fig. 962. LATERAL EXPOSURE OF THE LEFT KNEE JOINT.
The lateral condyle of the femur has been removed, and the leg has been forced medially to enlarge the cavity of the knee joint.

roughly transverse and corresponds anteriorly to the proximal border of the trochlea and posteriorly to the intercondyloid line. On the medial side the epiphysial line is on a level with the adductor tubercle. While the line lies at some distance from the capsule laterally, it may lie within the capsule in front and behind. Juxta-epiphysial infections of the diaphysis (acute osteomyelitis) invade the joint in front and behind more readily than laterally, but the epiphysial line is a strong barrier against distal spread of the infection.

In resection of the knee joint during the period of growth, little of the condyles can be removed without causing arrest of growth. Growth continues longest in this, the more active epiphysis, which, therefore, is a favorite site for infection or malignancy. Excessive growth at either extremity of the epiphysial line leads to the deformities of genu varum and genu valgum.

Proximal Extremity of the Tibia. The upper or condylar end of the tibia is its most expanded part, and presents an *articular surface*, commensurate with those of the femoral condyles (Figs. 961, 962). The articular surface of the two closely united tibial condyles forms a nearly horizontal plateau. This articulation presents two oval, slightly concave facets which are deepened by the menisci (semilunar cartilages) into fossae or sockets for the femoral condyles. The margins of the articular surfaces are depressed into a slight groove for the attachment of the menisci.

Between the two articular surfaces is a rough area surmounted by the *intercondylar eminence*, from which the double-spurred prominence of the tibial spine projects upward. Anterior and posterior to this eminence are flattened areas for the attachment of the corresponding crucial ligaments and the extremities of the menisci. A thumbbreadth distal to the anterior articular margin is the *tubosity of the tibia;* the broad, flat, intervening area is occupied by the infrapatellar bursa, bridged over by the ligamentum patellae. The head of the tibia slopes downward and forward to the tuberosity which is the upper limit of the anterior tibial crest. A flat facet on the posterolateral surface of the lateral condyle articulates with the head of the fibula.

The upper extremity of the tibia *develops* from one center of ossification which appears a short time before birth, and unites with the shaft about the twentieth year. From it are developed the two condyles and the tuberosity. The tuberosity may be formed from a separate center of ossification which fuses with the shaft at a later date. This sometimes is avulsed partly or wholly (p. 1009). The upper extremity of the tibia is the active epiphysis and the favorite site for osteosarcoma. In a young child the *epiphysial line* is close to the joint, so that in joint excision not more than a few millimeters should be removed.

Patella. The patella is a sesamoid bone developed within the tendon of the quadriceps muscle. It is irregularly triangular and is flattened anteroposteriorly (Figs. 945, 962). Its posterior surface is covered almost entirely by cartilage and is divided by a vertical ridge into two surfaces, which slope a little away from each other to the femoral condyles. The lateral of these surfaces is the larger. Frequently both surfaces are subdivided by two transverse ridges, so that three smaller faceted areas are observed on each side of the vertical median ridge. The rough, inferior part of the posterior surface of the patella is extra-articular and is related closely to the fat pad of the knee. The anterior surface of the patella is rough and is united intimately with the patellar tendon (ligamentum patellae). When the patella is fractured, the edges of the fragments may be covered with a veil formed by the torn outer fibers of the patellar tendon. Because the patella is practically without periosteum, the repair of fracture takes place chiefly in the bony substance.

In full flexion of the leg the patella glides into a position between the projecting femoral condyles and is seated partly in the intercondyloid fossa. When the leg is extended, only the inferior part of the patella is in contact with the trochlea.

The patella is cartilaginous at birth and *ossifies* from a single center which appears about the third year. Ossification usually is complete by the fifteenth year.

Head of the Fibula. The head of the fibula is thickened and pyramidal. Into the styloid process are inserted the fibular collateral ligament and the tendon of the biceps. *Ossification* begins about the third year from a single center and forms an epiphysis which unites with the shaft from the nineteenth to the twenty-second year. Separation of the proximal epiphysis is an unusual injury, but, when it

does occur, it may involve the common peroneal (external popliteal) nerve. Tuberculosis originating in the fibular diaphysis near the epiphysial cartilage usually does not spread to the proximal tibiofibular joint, since the epiphysial cartilage is entirely extracapsular. If, however, the disease originates in the proximal and lateral part of the tibial diaphysis, the proximal tibiofibular joint may be involved, for its capsule is attached partly to the tibial diaphysis.

KNEE JOINT. The knee joint, the largest and most complex of all the joints, combines strength and stability with a wide range and variety of motion, qualities seldom associated. It comprises the articulation between the patella and the trochlea, and the femorotibial joint. The femorotibial joint may be subdivided into medial and lateral femoro-menisco-tibial divisions, which are set apart by the incomplete partition formed by the ligamentum mucosum and the fat pad. Each condylar or femoro-menisco-tibial joint may be regarded as composed of femoromeniscal and meniscotibial divisions, for the synovial cavity on each side extends peripherally to the capsule, both above and below each meniscus.

The strength and varied function of the joint are the result of the complex formation and the powerful ligamentary structures uniting the bones and reinforcing the capsule. The tibiofibular joint stabilizes the knee by reinforcing the lateral tibial condyle and furnishing a firm point of attachment for the fibular collateral ligament.

From a brief examination of the joint one might be led to believe that its security is not great, considering how imperfectly the articular surfaces are adapted to one another, and taking into account the powerful leverage brought to bear upon the joint by the femur and the tibia, two of the longest and most powerful bones in the body. These apparent sources of weakness are more than overcome by the powerful ligaments which maintain the bone ends in contact and by the strong muscles with which they are surrounded. The proof of the strength of the joint is attested by the extreme rarity of traumatic dislocation of the head of the tibia, no matter how extreme the causative violence may be.

LIGAMENTS OF THE KNEE JOINT. The ligaments about the knee are divided into an extra-articular and an intra-articular group (Fig. 962). The EXTRA-ARTICULAR LIGAMENTS include the capsule, the quadriceps muscle and its tendinous expansions, the two collateral ligaments and the oblique popliteal ligament.

The *capsule* of the knee joint, which invests the bony ends of the joint as with a cuff, is a somewhat ill-defined structure anteriorly, where it stretches between the condyles of the femur and the head of the tibia on each side of the patella and the patellar ligament. The proximal line of attachment of the capsule includes the epiphysial line on the lateral and medial condyles of the femur, but remains at least 1 cm. distant from the margin of the articular surface. It is reinforced strongly by the patellar and infrapatellar portion of the quadriceps tendon. The capsule is overlaid by, and incorporated with, the tendinous expansions of the lateral and medial vasti (p. 1005), which, in turn, are invested by the fascia which extends over the joint and fuses with the deep fascia of the leg. Proximal to the patella and over the area occupied by it, the capsule is entirely deficient. Posteriorly, it is more clearly defined than elsewhere, and extends from the proximal margin of the articular surfaces and the intercondylar line to the posterior border of the head of the tibia; the femoral attachment coincides approximately with the epiphysial line. This part of the capsule is supported powerfully by the hamstring and gastrocnemius muscles. It is strengthened further by the *oblique popliteal ligament*, which extends obliquely across the back of the joint from the semimembranosus insertion to the medial border of the lateral femoral condyle. Many small spaces interrupt the continuity of the posterior capsule. A small aperture is often present in the part overlying the medial femoral condyle, through which the bursa beneath the medial head of the gastrocnemius communicates with the joint. On the lateral and medial aspect the capsule is short and strong.

The *quadriceps muscle*, its *tendinous expansions* and the *infrapatellar tendon* have been described (p. 1005).

The *tibial collateral* (*internal lateral*) *ligament* is a broad, flattened, straplike band which strengthens the capsule on its medial aspect. It is attached proximally to the medial condyle of the femur near the adductor tubercle and crosses the medial aspect of the joint,

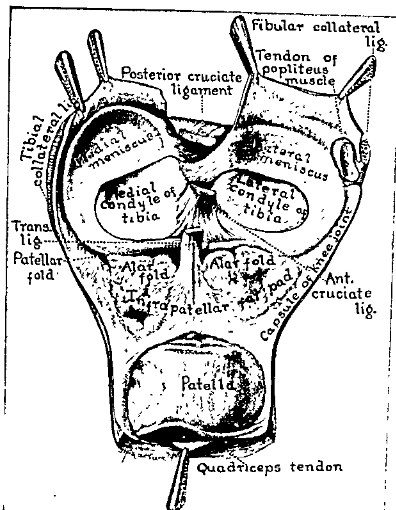


Fig. 963. STRUCTURES ON THE SUPERIOR ARTICULAR SURFACE OF THE LEFT TIBIA.

where it is attached firmly to the peripheral border of the corresponding meniscus. The ligament is attached distally to the medial border of the shaft of the tibia behind the attachment of the semitendinosus tendon. The *fibular collateral* (*external lateral*) *ligament* is a distinctly palpable rounded band attached to the lateral epicondyle of the femur, about 1 cm. proximal to the articular margin and the groove of origin of the popliteus tendon, over which it plays. As the ligament crosses the lateral aspect of the knee joint, it is separated from the joint by the popliteus tendon and its associated bursa. The ligament is attached distally to the head of the fibula. At its insertion the two slips of attachment of the biceps tendon, with an interposed bursa, embrace it. The ligament is overlaid by an expansion of the fascia lata prolonged backward from the iliotibial band.

Either of the collateral ligaments may be strained or torn by the same violent movement that causes injury to the menisci. When the collateral ligaments are torn, there is point tenderness over them; when the menisci are damaged, the tenderness is greatest over the joint line in the triangular depressions at the sides of the patellar ligament.

The more important of the INTRA-ARTICULAR LIGAMENTS are the cruciate ligaments and the menisci (Fig. 963).

The *cruciate ligaments* are strong, cordlike structures which extend from the intercondylar fossa of the femur to attachments in front of and behind the intercondylar eminence on the plateau of the tibia. The two cruciate ligaments, which may be termed the collateral ligaments of the bicondylar joints, cross each other in the center of the knee joint, and are a powerful stabilizing mechanism. They are intracapsular, but extrasynovial. The anterior cruciate ligament is attached to the tibia anterior to the intercondylar eminence, and passes upward and backward to an extensive insertion over the posterior part of the medial aspect of the lateral femoral condyle.

Since its points of attachment are farther from one another when the knee joint is freely extended, the ligament is tense in this position of the limb and bears the brunt of the strain of forced extension. The collateral ligaments and the thickened posterior part of the capsule, combined with the anterior cruciate ligament, are sufficient to prevent hyperextension of the joint, unless undue force is acting. Besides preventing hyperextension of the knee, the anterior cruciate ligament prevents the tibia from moving forward on the femur in passive extension of the joint. If, after injury, anterior movement of the tibia on the femur is obtained, a rupture of the anterior cruciate ligament is suspected. The posterior cruciate ligament is attached to the posterior part of the base of the intercondylar eminence of the tibia, and extends upward and forward to the lateral surface of the medial condyle of the femur. It is relaxed in extension of the leg, but tightened in flexion. It prevents backward movement of the tibia on the femur. In a severe strain of the knee one or both cruciate ligaments may be ruptured without causing actual dislocation of the joint.

The *menisci* (*semilunar cartilages*) are two sickle-shaped fibrocartilaginous wedges which form a circumferential investment for the head of the tibia and are interposed, wedgelike, between the tibial plateau and the head of the femur (Figs. 962 to 965). Each cartilage is attached by its thick peripheral border to the deep aspect of the joint capsule. In addition, the peripheral borders of the cartilages are attached to the margins of the tibial condyles by short fibrous bands known as coronary ligaments. The free medial margins of the cartilages are directed toward the joint cavity; their superior surfaces are concave, and their inferior surfaces are comparatively flat; both surfaces are invested by the synovial membrane of the joint. The menisci cover about two thirds of the articular surface of the tibia and accommodate themselves to the changing position of the joint by changes in their shape and position. They slide on the articular surfaces, and adjust themselves to the required weight-bearing demands of the femoral condyles. They glide backward in flexion and forward in extension, and, in the movements of rotation and torsion, one is carried forward and the other backward. The lateral meniscus is the smaller of the two; it is nearly circular in outline, and its two extremities are in close relationship, the anterior to the front of the intercondylar eminence (tibial spine), and the posterior to the interval between the tubercles of the eminence and to the posterior cruciate ligament. The lateral meniscus is related by its lateral and posterior aspect to the tendon of the popliteus muscle; a bursa intervenes, so that the synovial membrane of the knee joint projects laterally, both above and below it. It has no direct relation to the fibular collateral ligament. This arrangement, perhaps more than any other factor, is responsible for the great freedom of movement of this cartilage and, consequently, for the small likelihood of its derangement.

The medial meniscus forms almost a half circle, and its extremities are widely separated from one another. The anterior extremity is attached to a depression in front of the intercondylar eminence, and the posterior to a depression behind the eminence. The peripheral margin of the medial meniscus is firmly adherent to the broad and powerful tibial collateral ligament, and on this account is not freely movable. This fact explains the relative frequency of derangement of the medial meniscus in knee-joint strain or injuries involving the tibial collateral ligament (Fig. 964). The menisci are attached to each other anteriorly by the slender transverse ligament, which may be looked upon as the continuation of the peripheral fibers of each meniscus. This may be torn when a meniscus is deranged.

Synovial Membrane of the Knee Joint and the Infrapatellar Fat Pad. The synovial membrane lining the knee joint is the most extensive of its kind in the body, and its arrangement is complicated by the presence of the intra-articular ligaments and menisci (Figs. 962, 965). It lines the deep aspect of the capsule of the joint, covers the infrapatellar fat pad and the femoral and tibial surfaces of the menisci, and helps to attach their peripheral margins to the tibia. A large synovial pouch balloons upward between the quadriceps muscle and the shaft of the femur, where it forms the subquadriceps (suprapatellar) bursa. This bursa may be infected by stabs or punctures and thereby initiate joint infection, or it may be involved by fracture of the lower end of the femur and result in hemarthrosis. The synovia forms culs-de-sac about the lateral surfaces of the condyles, cov-

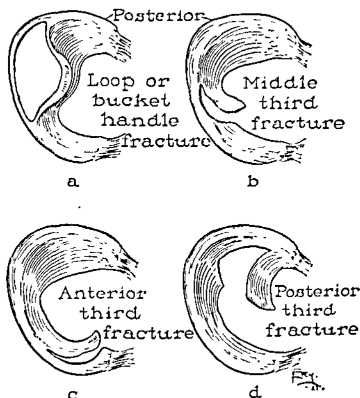


Fig. 964. COMMON TYPES OF FRACTURE OF THE MEDIAL SEMILUNAR CARTILAGE. (From Henderson: S. Clin. North America, 27: 1425–31, 1927.)

ering them for a third of their anteroposterior depth. The popliteus tendon is in contact with the synovial membrane in the intra-articular part of its course. It is through the medium of the bursa between this tendon and the posterior aspect of the head of the fibula that the knee-joint synovial membrane often is brought into connection with the synovial membrane of the proximal tibiofibular joint. A communication sometimes is present between the knee-joint synovial membrane and the bursa beneath the inner head of the gastrocnemius. In the posterior part of the joint the cruciate ligaments push the membrane forward from the capsule into a synovial duplication. The membrane thus covers both cruciate ligaments in front and on each side, rendering them extrasynovial.

The large, pyramidal INFRAPATELLAR FAT PAD lies distal to the apex of the patella and behind the superior portion of the patellar tendon (Figs. 962, 963, 965). It is extra-articular and extrasynovial, and is thickest in its *body*, which lies in the median plane. From the body extend lateral free margins or processes, known as *alar folds* (*ligamenta alaria*). Because of its semifluidity, the fat pad conforms to the shape of the trochlea and intercondylar spaces. The *patellar synovial fold* (*ligamentum mucosum*) extends upward from the centrally placed apex of the pad to the intercondyloid notch of the femur. A portion of the main fat pad on its lateral or superior prolongation frequently is the seat of hypertrophy (*lipoma arborescens*), in which grapelike proliferations may become detached and form loose bodies in the joint cavity. Similar hypertrophy may affect the fat pad lying between the femur and the suprapatellar bursa.

MOVEMENT AT THE KNEE JOINT. The principal movements at the *femorotibial joint* are flexion and extension. The mechanism by which these movements are effected differs from that in a true hinge joint, since the changes of attitude are accompanied by a slight gliding movement of the head of the tibia backward and forward on the condyles of the femur and by a certain degree of torsion or rotation (screw movement) of the tibia about its longitudinal axis. Because of the gliding movement between the femur and the tibia, the socket formed by the articular surface of the tibia and the menisci does not revolve upon a fixed transverse axis passing

through the femoral condyles, but upon axes that vary with the different attitudes of the knee.

In semiflexion there is allowed the greatest amount of rotary movement, and this is the position of greatest instability. In complete extension of the leg, as in standing, the joint is locked strongly against lateral and rotary motion; the femur rotates a little mesially as a terminal stabilizing movement. Further extension is opposed by the tension of the anterior cruciate, collateral and posterior ligaments and the hamstring muscles.

In passing from the extended to the flexed position, the slight lateral rotation of the tibia accompanying extension disappears before semiflexion is reached. In full flexion the collateral and posterior ligaments are relaxed, and a slight amount of rotary movement of the tibia upon the femur is possible. Excessive medial rotation is checked by the cruciate ligaments, and lateral rotation is checked by the lateral ligaments.

Adduction, abduction and lateral sliding of the tibia occur at the knee only in abnormal circumstances and are the result of torn collateral and cruciate ligaments. Since movements are at their minimum in extension of the leg, clinical examination should be made with the knee joint in that position.

In considering the *movements at the patello-femoral joint*, it will be found that complete coaptation between the two articular surfaces does not occur, but that, as the knee passes from extension into flexion, the facets of the patella make and break contact with the trochlea. As flexion occurs, the middle patellar facets come into contact with the inferior part of the trochlea. When flexion is carried still further, the superior patellar facets lie against the most inferior part of the trochlea, and in complete flexion most of the articular surface

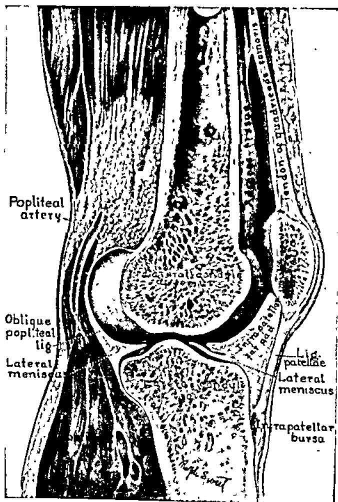


Fig. 965. SAGITTAL SECTION THROUGH THE KNEE.

of the patella is apposed to the intercondylar notch.

Surgical Considerations

GENU VALGUM (KNOCK KNEE). Under normal conditions a line dropped from the center of the head of the femur passes between the femoral condyles at the knee joint. In this way the superincumbent weight is transferred to the foot through the center of the knee, the tibial shaft and the center of the ankle joint. In rickets, because of irregular growth and ossification at or near the epiphysial line, there may take place an abnormal degree of downward growth in the medial part of the distal extremity of the femoral diaphysis; this results in the thrusting of the medial part of the epiphysis downward, backward and laterally instead of straight downward. Thus there arises the condition known as genu valgum, or inward bowing of the knee (Fig. 966). There is, in addition, bending of the femur and tibia close to the joint, so that a line dropped from the femoral head passes lateral to the center of the knee joint. The outward deflection of the leg may be such that the angle between the long axes of the femur and tibia, normally about 170 degrees, may approach a right angle. In addition, the foot usually is everted into the splayfoot deformity of talipes valgus.

In some instances flatfoot may be the cause and not the result of genu valgum. Many young adolescents with pronated feet adopt a position of rest in which the feet are everted and separated widely, while the knees are flexed and the thighs adducted. In this position the medial condyle of the femur is tilted off the tibia, and the tibial collateral ligament is stretched. The body weight is borne by the lateral femoral condyle, thus bringing about a diminished pressure on the medial part of the epiphysial cartilage. As a result of this postural defect, the medial distal part of the femoral diaphysis undergoes an abnormal growth, and the apparent genu valgum of rest becomes a true genu valgum.



Fig. 966. GENU VALGUM (KNOCK KNEE). (Lovett, in Keen's Surgery.)

When knock knee occurs from infantile paralysis, there is often a certain amount of flexion and lateral rotation of the leg and some contracture of the hip joint. An important factor in producing this deformity is the powerful pull on the tibia exerted by the iliotibial band which, through its pelvic and thigh attachments, summarizes the power of the gluteus maximus and medius and the tensor fasciae latae muscles. In advanced genu valgum the femur requires osteotomy (Fig. 967); the tibia is osteotomized to correct torsion, and the iliotibial band is divided to correct hip and knee flexion. These operative procedures are supplemented by suitable apparatus to maintain the corrections.

The disability caused by genu valgum may be relieved by medial cuneiform osteotomy of the femur and, in exaggerated cases, by transplanting the tibial tuberosity and the insertion of the patellar tendon into the medial aspect of the tibia.

In *supracondylar wedge osteotomy* an incision down to the femur is made over the medial aspect of the thigh, a fingerbreadth inferior to the most proximal part of the femoral trochlea and the same distance in front of the tendon of the adductor magnus. No vessel is encountered, save possibly the supreme geniculate (anastomotica magna) artery, which usually lies more posteriorly. The femur is divided transversely with an osteotome above the epiphysial line for a distance of two thirds or more of the thickness of the bone, and a wedge of bone is removed; the remaining part is fractured by bending the limb forcibly. An osteotomy of the femur may be performed from the lateral surface of the limb, the incision for which readily avoids the epiphysial line and the superior geniculate and superior articular

arteries. Linear or simple osteotomy on the lateral aspect of the femur is indicated in genu valgum, and lateral wedge osteotomy may be performed for genu varum.

Osteotomy of the tibia below the condyles may be required to complete the remedy of the knock-knee deformity (Fig. 967). The bone is exposed on its medial surface just below the tuberosity and is divided with an osteotome. As in osteotomy of the femur, two thirds or more of the bone is cut and the remainder is fractured forcibly. To obviate the danger to the common peroneal nerve by forcible stretching, the cuneiform type of osteotomy should be performed.

GENU VARUM (BOWLEGS). Overgrowth of the lateral part of the distal extremity of the diaphysis of the femur, or of the superior part of the tibial diaphysis, is one of the features of rickets. This results in outward bowing of the legs, or genu varum. The weight of the body contributes to the deformity by causing bending in the bones of the thigh and leg. The point of greatest bending may be near the ankle or near the knee joint, but will be lateral to the center of the ankle joint. Consequently the body weight is distributed mainly over the lateral part of the foot, which is well adapted to bear the increased strain, and little disability is encountered.

If the child is kept off his feet, the bones usually regain their normal shape when the rachitic softening disappears and the bones become more brittle. Designed fracture (osteoclasis) or cuneiform osteotomy may be necessary to overcome the deformity. Dietetic treatment and corrective-pressure methods assist the natural tendency toward self-correction and usually are sufficient to restore the condition to normal.

DISLOCATION AT THE KNEE JOINT. The knee rarely is dislocated, and then only by extreme trauma or after severe infection. In traumatic dislocation the tibia may be luxated forward, backward (Fig. 968) or to either side, or it may be rotated upon the femur. The usual mechanism of dislocation is extreme hyperextension and torsion. The laceration of the soft tissues may be so extensive as to rupture the popliteal vessels and require amputation. If the luxation is caused by weakening of the knee joint by disease, the powerful hamstring muscles tend to pull the tibia backward, producing a deformity difficult to correct.

INJURIES OF THE MENISCI. The menisci rarely become detached in their entirety, but a portion of one of them may be torn partly or completely loose (Fig. 964) and be caught between the tibial and femoral articular surfaces, causing characteristic symptoms. Forcible extension of the leg, accompanied by forcible rotation of the flexed or semiflexed

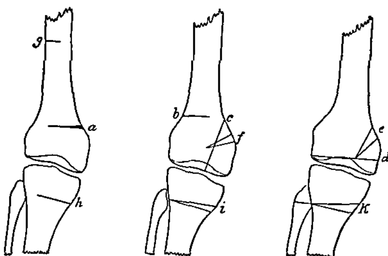


Fig. 967. LINES OF OSTEOTOMY ABOUT THE KNEE.

a, Transverse, wedge-shaped osteotomy of the medial femoral condyle; *b*, linear osteotomy superior to the lateral condyle; *c*, linear osteotomy of the medial femoral condyle; *d*, linear osteotomy of both femoral condyles; *e*, *f*, oblique, wedge-shaped osteotomies of the medial femoral condyle; *g*, linear osteotomy of the femoral shaft; *h*, linear osteotomy of the medial tibial condyle; *i*, wedge-shaped osteotomy of the medial tibial condyle; *k*, wedge-shaped osteotomy of the medial condyle of the tibia and linear osteotomy of the head of the fibula. (Warbasse.)

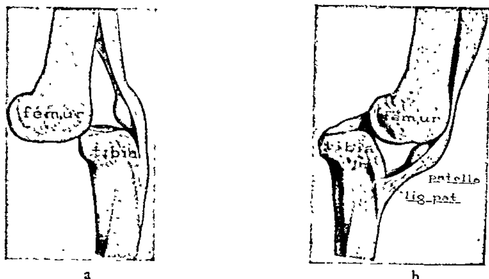


Fig. 968. DISLOCATION OF THE TIBIA AT THE KNEE JOINT.

a, Anterior dislocation. *b*, Posterior dislocation. (From Babcock: Textbook of Surgery.)

knee, such as occurs in certain occupations and in violent sports, is a common cause of an accident of this sort. Catching the foot in a hole while running is a frequent cause. The accident may occur when the tibia is rotated on the flexed femur, or when the femur is rotated on the flexed tibia. The medial meniscus is much more likely to be injured than is the lateral meniscus. The comparative immunity of the lateral meniscus probably is the result of its greater range and freedom of movement (Fig. 969).

When the femur is rotated laterally on the fixed tibia suddenly and violently, the lateral meniscus readily follows the lateral femoral condyle and, in so doing, throws a strain on the anterior extremity of the medial meniscus through the transverse ligament. The anterior part of the medial meniscus may be split, or its forward extremity may be torn from its tibial attachment and be dragged toward the center of the joint. Violent flexion of the knee, combined with medial rotation of the femur on the tibia, may tear away the anterior or anterolateral attachments of the medial meniscus. The most common lesions are a transverse tear of the meniscus near the collateral ligament, detachment of the anterior insertion, and partial concentric splitting. Occasionally the capsule of the knee joint becomes sufficiently relaxed to permit a slight amount of abduction and adduction; this predisposes to meniscal injury, since the slight separation between the femur and tibia renders the menisci more likely to be caught between the articular surfaces.

If a part of the cartilage actually is displaced, the joint cannot be extended completely, and often fills with fluid. There is likely to be

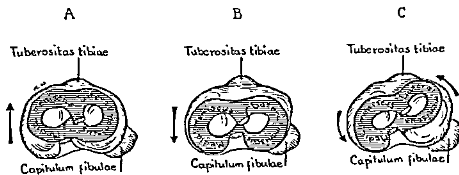


Fig. 969. GLIDING MOVEMENTS OF THE MENISCI ON THE TIBIAL PLATEAU IN FLEXION, EXTENSION AND MEDIAL TORSION OF THE LEG.

A, The menisci glide forward in extension. *B*, The menisci glide backward in flexion. *C*, Movements of the menisci in medial rotation; the lateral meniscus moves forward and the medial meniscus backward. (After Forgue.)

acute localized tenderness at some palpable point along the joint line, especially over the tibial margin medial to the patellar tendon. Use of the limb is extremely painful until the cartilage is released. Derangement of the knee joint from an injured cartilage is subject to recurrence from trivial causes. Removal of the cartilage entails no ill effects. Total removal of the cartilage is necessary rather than partial removal, such as removal only of the bucket-handle or torn fragment. The medial meniscus can be removed either by means of the medial parapatellar incision or the medial approach to the knee joint with a single cutaneous incision and a double capsular incision.

TUBERCULOSIS OF THE KNEE JOINT. Tubercle bacilli and the organisms of pyogenic osteomyelitis usually lodge in the ends of the diaphyses about the knee joint. Direct tuberculous infection of the synovial membrane from the blood stream undoubtedly occurs, and occasionally the process begins in the epiphysis itself (epiphysitis). The knee joint (Fig. 971) is second only to the hip joint in the frequency of tuberculous involvement.

Tuberculosis of the distal end of the femur begins in the distal part of the diaphysis nearer the posterior than the anterior surface. The focus may spread proximally along the diaphysis or pass directly outward toward the surface. In the latter instance it usually

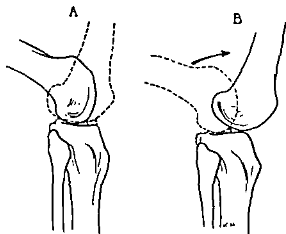


Fig. 970. DIAGRAM TO SHOW THE ANTERIOR AND POSTERIOR GLIDING OF THE MENISCI ON THE TIBIAL PLATEAU AND ONE MECHANISM OF MENISCUS INJURY.

A, The meniscus, in accommodating the femoral condyles, glides backward in flexion. The femur (in dotted lines) shows how the meniscus is pressed forward in extension. *B*, Illustrates how the meniscus may be caught between the femur and the tibia in a rapid movement from flexion to extension. (After Forgue.)



Fig. 971. TUBERCULOSIS OF THE KNEE JOINT WITH FLEXION DEFORMITY AND SINUS FORMATION.

(From Lovett, in Keen's Surgery.)

spreads backward and breaks through the cortical bone of the popliteal surface of the femur, causing a popliteal abscess. Tuberculosis from this focus may involve the joint, but usually does not, since the lesion is extracapsular and the infection finds less difficulty in passing to the popliteal fossa than in eroding the epiphysis and entering the joint.

When *tuberculous involvement begins in the proximal end of the tibial diaphysis*, it is entirely extracapsular and may spread distally along the shaft. The focus may spread circumferentially and finally involve the joint, either at the reflexion of the synovia, or by eroding the epiphysis and the articular cartilages. Occasionally the disease may extend directly through the articular cartilage and involve the proximal tibiofibular joint. If this joint communicates with the knee joint by the popliteal bursa, the knee joint is infected secondarily.

When the infection is communicated to the synovial membrane, a reaction is set up and fluid is secreted. As the involvement of the membrane increases, it becomes the seat of an extensive growth of granulation tissue. The newly formed tissue fills the available space within the joint, giving it the appearance of a

traumatic synovial effusion, a condition with which it may be confused. The articular cartilages of the femur, patella and tibia are destroyed gradually, and the subjacent cancellous tissue of these bones then becomes the seat of a fungating caries. A noteworthy feature of a tuberculous lesion, in contrast to a lesion caused by pyogenic infection, is that the *cartilaginous surface is preserved for a considerable period* as a thin shell. This tendency, detected in roentgenograms, is of some differential diagnostic import. The intra-articular and extra-articular ligaments become progressively infiltrated, softened, and weakened to the degree that the joint acquires an abnormal lateral and anteroposterior mobility. The granulation tissue undergoes coagulation necrosis, and chronic abscesses may make their way to the surface. Their ultimate evacuation, spontaneous or surgical, frequently is succeeded by persisting sinuses.

While these changes are occurring within the joint, the thigh and leg muscles undergo wasting until the knee assumes a spindle-shaped outline. Unless suitable precautions are taken, the knee joint becomes more and more flexed; the tibia may be subluxated backward and rotated laterally by the action of the hamstring and biceps muscles. The action of the hamstring muscles in pulling the tibia backward is facilitated by degeneration of the ligaments in and about the knee.

ASPIRATION OF THE KNEE JOINT. Aspiration of the joint may be required to relieve pressure, obtain fluid for bacteriological study, evacuate a recently extravasated bloody effusion, or irrigate the joint cavity. The site for puncture should be somewhat proximal and lateral to the patella through the tendinous part of the vastus lateralis muscle, rather than through the corresponding area on the medial aspect where the fleshy vastus medialis is encountered. The needle or trocar is carried distally toward the middle of the joint.

SURGICAL APPROACHES TO THE KNEE JOINT. Arthrotomy, or opening into the knee joint, is performed through a variety of incisions devised to reach particular parts with the least disturbance of the muscular mechanisms and supportive ligaments about this active weight-bearing joint. The *anteromedial approach* (Fig. 972) is the basic incision for extensive operation on the knee, as in débridement, synovectomy and complete anterior exploration of the joint. The *anteromedial approach of Coons and Adams* (Fig. 973) provides wide exposure of the joint, but should be rarely used because the forklike cutting of the quadriceps tendon often heals with limitation of full extension of the knee. A good modification is the anteromedial skin approach and then detachment of the tibial tubercle with the insertion of the infrapatellar tendon and retraction of the muscle mass upward. The tibial tubercle can be easily replaced and, if necessary, securely fixed with a single screw. The *anterolateral (Kocher) approach* (Fig. 974) gives good exposure to the lateral compartment of the knee, but occasionally the healing incision will cause just enough retraction to permit recurrent subluxation or dislocation of the patella. Unless a wide exposure of the lateral compartment is needed, many surgeons prefer to use the anteromedial approach (Fig. 972). The *medial approach* (Fig. 975) is a good incision for removing the medial meniscus and has several minor variations of the skin incision. The *posteromedial incision of Henderson* (Fig. 976) is a good standard approach for pathologic conditions localized to the posterior and medial aspects of the joint. Klein has also described a *posteromedial approach* (Fig. 977). A *posterolateral approach* to the knee joint (Fig. 978) gives good access to the posterolateral compartment.

EXCISION OF THE KNEE JOINT. Excision of the knee joint is performed most frequently for tuberculosis, and the best surgical access is afforded by a long, curved median parapatellar incision. The incision divides the superficial tissues, the capsule and its reinforcements, and the infrapatellar tendon, opening the knee joint. The joint may be exposed widely by flexing the knee (Fig. 978).

The aim of the operation is the removal of the articular extremities of the femur, tibia and patella, and the excision of the diseased synovial membrane as thoroughly as possible. The ultimate result of the operation is a rigid joint.

Frequently the most extensive area of disease is located beneath the quadriceps muscle in the subquadriceps bursa. This bursa reaches a palmbreadth above the patella and is continuous with the synovial membrane overlying the superficial aspect of the femoral condyles. This large synovial pouch is dissected carefully from the overlying muscle and the underlying fat pad on the anterior surface of the femur.

The removal of the cruciate ligaments facilitates the dissection of the synovial membrane from the lateral and medial parts of the posterior division of the capsule. In these situations synovial pouches extend upward behind the condyles; if they are not removed, the disease may recur. In dissecting diseased synovial membrane from the posterior part of the joint, the proximity of the popliteal artery makes caution necessary. The point at which the synovial membrane comes most intimately into relation with the vessel is opposite the posterior part of the tibial plateau. The middle genicular artery may be ligated where it enters the joint after piercing the posterior popliteal ligament.

After resection of the cruciate ligaments a stable and movable joint cannot be obtained, and, since stability is of paramount importance, bony ankylosis in slight flexion is essential. This result is achieved by removing the articular cartilage and a layer of bone from the tibial and femoral condyles and from the patella. The anterior articular surface of the femoral condyles should be removed to render ankylosis more secure. When the disease lies mainly in the synovial membrane, and the bone is not involved seriously, only that thickness of bone

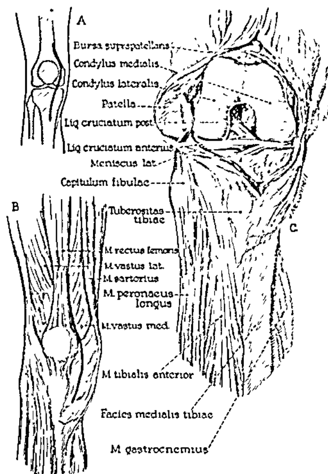


Fig. 972. ANTEROMEDIAL APPROACH TO THE KNEE.

A, The incision begins at the medial edge of the quadriceps tendon, 3 to 4 inches above the knee, extends downward, and curves gracefully around the medial edge of the patella to end just below the tibial tubercle. *B*, The subcutaneous tissue and fascia are divided, and the incision is deepened between the vastus medialis muscle and the quadriceps tendon. The capsule and synovial membrane are incised along the medial edge of this tendon, then alongside the patella and patellar ligament. *C*, The patella is retracted laterally as the knee is flexed toward a right angle. This gives an excellent view of the lower end of the femur, cruciate ligaments, internal and external menisci and the articular surface of the patella. The knee is extended for closure of the wound. Special emphasis should be placed on suture of the vastus medialis to the medial border of the patella. This is essential to ensure prompt recovery of active extension of the knee.

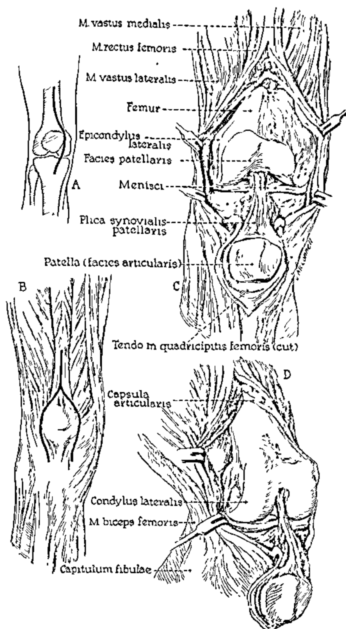


Fig. 973. ANTEROMEDIAL APPROACH TO THE KNEE JOINT (COONS AND ADAMS).

A, Five-inch vertical incision, beginning at the medial border of the quadriceps tendon about 3 inches above the patella, and extending downward to curve around the patella and end about the tibial tubercle. *B*, The quadriceps tendon is divided by a 2-pronged fork incision, the short handle beginning at the musculotendinous margin and extending downward to divide ½ *inch* above the patella, where the prongs pass medially and laterally around the patella and patellar ligament to a point about the level of the tibial tubercle. The fact that the most medial and lateral fibers of the quadriceps tendon expansion are not cut by this incision partially compensates for the major division of this tendon. In line with this incision, the joint capsule and synovial membrane are divided to the level of the articular surface of the tibia. *C* and *D*, The patella and patellar ligament are retracted downward, and the knee is flexed to 90 degrees. Retraction of the medial and lateral articular capsule then gives an excellent exposure of the anterior joint structures.

should be removed which will assure osseous union. In adults the line of bone section of the femur should be below the upper margin of its trochlear surface, which is at a point just distal to the attachment of the collateral ligaments. In order to gain proper thigh-to-leg alignment, the line of section of the femoral condyles should be parallel to the joint line and not at a right angle to the long axis of the bone. The tibial section should be parallel to the articular surface of the bone, and the segment removed will vary from 0.5 to 1 cm. in thickness. After fixing the femoral condyle against the tibial condyles and fixing the patella against both bones, the anterior flap of skin and fascia is replaced and sutured.

The amount of actual permanent shortening usually is small, but serves to keep the foot from dragging on the ground when the patient walks again.

In young people and in those whose skeletal growth is not yet complete it is obviously undesirable to perform an extensive resection of these bones, since this leads to a shortened and poorly developed limb. It is of the greatest importance, therefore, that the line of bone section should be upon the articular sides of the epiphysial cartilages. In children the safest course is to shave off only the articular cartilages and to remove the diseased parts of the bones with a gouge, leaving as much of the epiphysis as possible.

Injuries to the Lower Extremity of the Femur and Upper Extremity of the Tibia. *Separation of the lower epiphysis of the femur* usually occurs in young boys, from violent

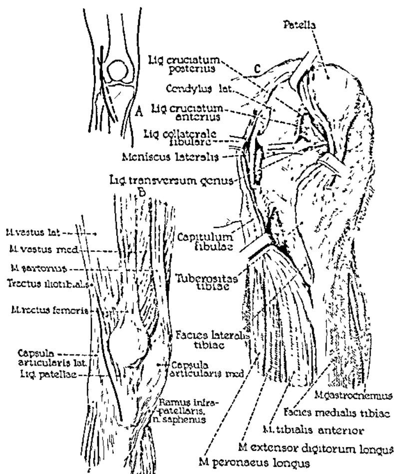


Fig. 974. ANTEROLATERAL (KOCHER) APPROACH TO THE KNEE JOINT.

A, Slightly curved or straight incision over the anterolateral aspect of the knee, beginning over the vastus lateralis muscle 2 to 3 inches above the patella and extending downward and medially to 1 inch below the tibial tubercle. *B*, In line with the skin incision and ½ inch lateral to the patella, the articular capsule and synovial membrane are incised. *C*, With the knee flexed to a right angle, good lateral and medial retraction exposes the lateral femoral condyle, lateral meniscus, anterior cruciate ligament and upper lateral aspects of the tibia.

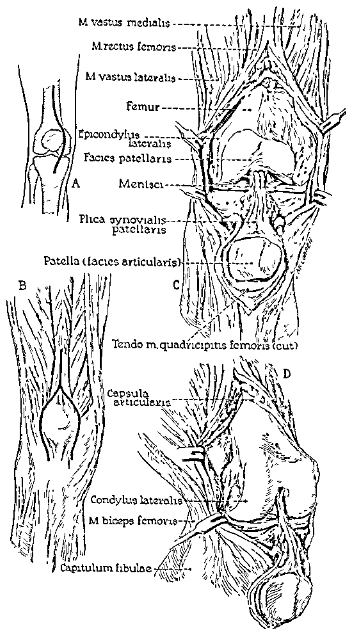


Fig. 973. ANTEROMEDIAL APPROACH TO THE KNEE JOINT (COONS AND ADAMS).

A, Five-inch vertical incision, beginning at the medial border of the quadriceps tendon about 3 inches above the patella, and extending downward to curve around the patella and end about the tibial tubercle. *B*, The quadriceps tendon is divided by a 2-pronged fork incision, the short handle beginning at the musculotendinous margin and extending downward to divide ½ inch above the patella, where the prongs pass medially and laterally around the patella and patellar ligament to a point about the level of the tibial tubercle. The fact that the most medial and lateral fibers of the quadriceps tendon expansion are not cut by this incision partially compensates for the major division of this tendon. In line with this incision, the joint capsule and synovial membrane are divided to the level of the articular surface of the tibia. *C* and *D*, The patella and patellar ligament are retracted downward, and the knee is flexed to 90 degrees. Retraction of the medial and lateral articular capsule then gives an excellent exposure of the anterior joint structures.

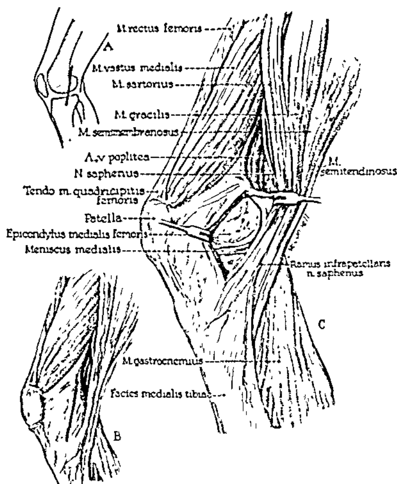


Fig. 976. POSTEROMEDIAL APPROACH TO THE KNEE JOINT.

A and *B*, With the knee in moderate flexion, a 2½-inch incision is made anterior to the relaxed hamstring muscles, beginning just posterior to the adductor tubercle and extending downward and slightly forward to the medial side of the tibia. *C*, The joint capsule is incised in the same line and, on anterior and posterior retraction, the posterior and medial compartments of the knee joint are readily exposed.

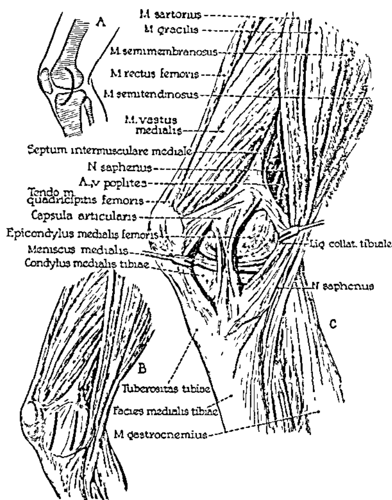


Fig. 975. MEDIAL APPROACH TO THE KNEE JOINT.

A, Posteriorly curved 3-inch incision, beginning 1 inch medial to the medial border of the patella and extending downward and forward to the patellar ligament (Fischer). A variation of this (Sir Robert Jones) is an anteriorly curved 3-inch incision beginning ¾ inch medial to the medial edge of the patella and extending downward and backward to the level of the tibial plateau. Gave and Bosworth advise a posteriorly curved incision beginning 1½ inches posterior to the middle of the patella and extending downward and sharply forward just below the top of the tibia to the patellar ligament.

In making these incisions, special care should be taken to avoid damage to the saphenous nerve and its anteriorly coursing infrapatellar branch. As shown in *C*, it pierces the fascia lata between the tendons of the sartorius and gracilis muscles about the level of the knee joint and spreads anteriorly.

B, Line of joint incisions. *C*, For exposure of the anterior joint space a 1½- to 2½-inch longitudinal incision is made through the capsule and synovia approximately ½ inch from the patellar border. For excision of the posterior horn of the medial meniscus or for loose bodies in the posterior compartment, the skin and subcutaneous fascia are strongly retracted posteriorly with the knee flexed to 45 degrees. A second longitudinal incision is made approximately 1 inch posterior to the anterior incision, behind the medial collateral *ligament*.

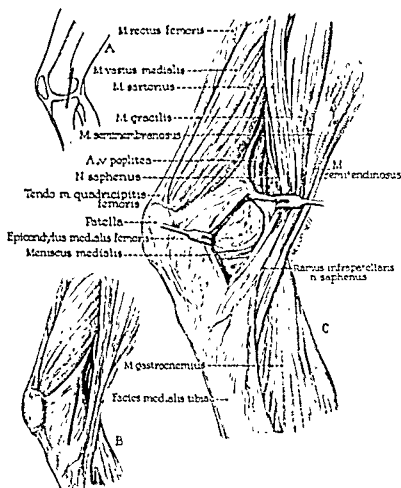


Fig. 976. POSTEROMEDIAL APPROACH TO THE KNEE JOINT.

A and *B*, With the knee in moderate flexion, a 2½-inch incision is made anterior to the relaxed hamstring muscles, beginning just posterior to the adductor tubercle and extending downward and slightly forward to the medial side of the tibia. *C*, The joint capsule is incised in the same line and, on anterior and posterior retraction, the posterior and medial compartments of the knee joint are readily exposed.

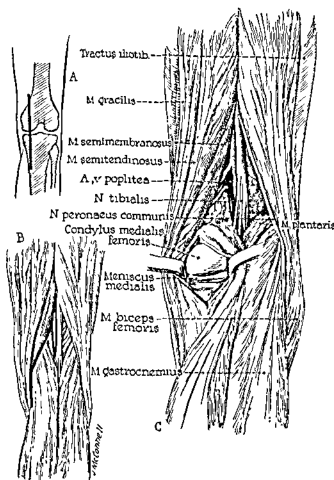


Fig. 977. POSTEROMEDIAL APPROACH (KLEIN) TO THE KNEE JOINT.

A, Four-inch vertical incision over the posteromedial aspect of the knee joint, with its center at the joint line. *B*, The subcutaneous tissue and fascia are incised and the wound deepened by blunt dissection through the cleavage plane between the semitendinosus and medial head of the gastrocnemius muscles, which are retracted medially and laterally, respectively. *C*, This dissection exposes the joint capsule over the medial femoral condyle. The capsule is incised down to the popliteus muscle, bringing into view the medial femoral condyle, the medial meniscus and the upper posterior aspect of the tibia.

overextension and rotation of the leg. A common mechanism is for the leg to be twisted between the spokes of a revolving wheel (wagon-wheel fracture). The movement throws a severe strain on the posterior part of the capsule, which is strong and does not give way. The strain, therefore, is transmitted to the distal femoral epiphysis; fracture separation takes place through that part of the metaphysis which abuts on the epiphysial cartilage. The displacement may be slight, but, when considerable, thrust the femoral shaft backward into the popliteal space behind the epiphysis; the gastrocnemius muscle remains attached to the epiphysis. The injury often is complicated by injury to the popliteal vessels so extensive as to require amputation. Reduction is obtained under full anesthesia by *flexing the knee and* drawing the lower fragment downward by downward traction on the foot and forward traction on the upper tibia. By lifting the femur forward, the fragments come together much as in a dislocation. Future growth depends on the accurate reposition of the epiphysis.

Supracondylar fracture of the femur (p. 993) sometimes is converted into a T-*shaped intercondylar fracture* by a vertical splitting of the distal fragment (Fig. 980, *A*). The knee is broadened by the spreading of the distal fragments by the gastrocnemius muscle. The thigh muscles, acting on the leg, drag it and the attached distal fragment of the femur proximally until the distal fragment overlies the proximal fragment in front. There is usually a considerable effusion into the joint.

Manipulations to restore the proper alignment *are carried out with the knee flexed* to relax the gastrocnemius muscle. If these fail,

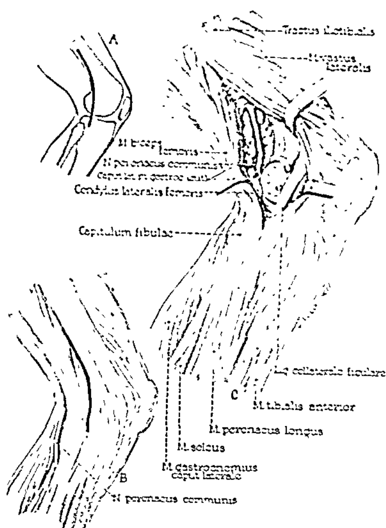


Fig. 978. POSTEROLATERAL APPROACH (HENDERSON) TO THE KNEE JOINT.

A, With the knee slightly flexed, a 3-inch curved incision is made just anterior to the biceps femoris tendon and the head of the fibula. *B*, In line with the skin incision, the posterior expansion of the iliotibial tract is incised, and the main portion of the tract and the vastus lateralis muscle are retracted anteriorly, and the biceps femoris posteriorly. The common peroneal nerve on the posterolateral aspect of the head of the fibula should be identified and avoided. *C*, The lateral head of the gastrocnemius is cut and the joint capsule divided. With pronounced anterior and posterior retraction, the posterolateral compartment of the knee is thus exposed.

Ligamentum patellae
Plica synovialis patellae
Plica alaris
Pars synovialis capsulae articularis
Facies patellaris femoris
Infrapatellar fat pad
Facies articularis patellae
Cavum articulare
Bursa suprapatellaris
Condylus medialis femoris
Meniscus medialis
Ligamentum cruciatum posterius
Condylus lateralis femoris
Plica synovialis patellaris
Ligamentum cruciatum anterius
Infrapatellar fat pad

Fig. 979. WIDE EXPOSURE OF THE LEFT KNEE JOINT THROUGH A U-SHAPED INCISION.

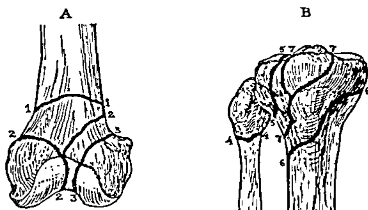


Fig. 980. COMMONER FRACTURE LINES IN THE DISTAL EXTREMITY OF THE FEMUR AND THE PROXIMAL EXTREMITIES OF THE TIBIA AND FIBULA.

A, Fracture lines in the distal extremity of the femur. *B*, Fracture lines in the upper extremities of the tibia and fibula. 1-1, Supracondylar fracture of femur; 2-2-2, intercondylar Y-fracture; 3-3, fracture of medial condyle of femur; 4-4, fracture of neck of fibula; 5-5, fracture of lateral condyle of tibia; 6-6, infracondylar fracture of tibia; 7-7-7, intercondylar Y-fracture of tibia.

traction treatment with a Steinmann pin passed through the crest of the tibia is required to align the fragments. In a T-shaped fracture the distal fragments may be approximated by pressure against the femoral condyles with the knee in flexion.

Fracture of the tibial condyles almost invariably invades the knee joint and deforms the tibial articular surface. The injury ordinarily results from the shearing force of one or the other femoral condyle. One whole side of the tibial plateau may be driven downward, leaving the joint asymmetrical. A strong lateral strain upon the knee, as produced by a blow from an automobile bumper, may drive the lateral tibial condyle downward and impact it (bumper fracture). Occasionally an intercondylar fracture occurs in which the tibial shaft is driven upward between the lateral fragments or the femoral shaft is driven downward between the split condyles. The articular surface is broadened, and one or the other articular surface may be so depressed as to cause genu varum or genu valgum. Treatment is designed to restore the normal place and shape of the articular surface. A depressed condylar fragment may require open reduction.

In *infracondylar fracture of the tibial shaft* proper alignment is of great importance to prevent genu recurvatum (Fig. 980, *B*).

Fracture of the intercondylar eminence of the tibia occasionally occurs from forcible extension of the femur upon the fixed and medially rotated tibia (Fig. 980, *B*). In a similar way, forcible extension of the femur with the tibia fixed causes the lateral femoral condyle to fracture the lateral tubercle of the eminence. Absolute rest in the extended position usually produces a good result; open operation may be necessary. The best exposure is obtained through the median longitudinal incision, which splits the patella vertically.

Separation of the tibial tuberosity has been described (p. 1009).

CHAPTER 37

Leg

The skeletal structure of the leg is made up of the tibia and fibula. The tibia is constructed strongly, and bears most of the weight of the body through its articulation with the femur above and the talus below. The fibula is slender and lies behind and to the lateral side of the tibia. The bones of the leg furnish insertions to the thigh muscles and attachments to the leg muscles which control the foot. The muscles spanning the knee and ankle are largely responsible for the contractures at these joints and increase the difficulty of maintaining fracture fragments in position. Fractures of the leg bones, therefore, require immobilization of the thigh and foot.

In topographic study the upper limit of the leg is defined as the horizontal plane at the level of the inferior part of the tuberosity of the tibia, and the lower limit as a plane through the bases of the malleoli.

BONY LANDMARKS. The well developed leg is conical in outline, smooth and uniformly rounded in children and females, but irregular in males because of muscle development. The muscles may be brought prominently into relief if made to contract, as they do in the effort to stand on tiptoe.

The *tuberosity of the tibia* is a prominent bony landmark. The *medial surface of the tibia*, below the level of the insertion of the sartorius and semitendinosus muscles, is covered by the skin and superficial fascia only, and can be palpated through its entire length. The finger passed over it readily detects any irregularity on its surface. The sharp anterior border or *crest of the tibia*, "the shin," is a distinct landmark which begins at the tibial tuberosity and descends in a slightly curved fashion to the talocrural (ankle) joint. In the lower third of the bone the crest loses its sharpness and merges into the evenly rounded tibial shaft. The medial margin of the tibial shaft, although less distinct than the anterior margin, can be palpated through its entire length.

The *shaft of the fibula* in its upper three fourths is concealed by the anterior and lateral groups of leg muscles and cannot be palpated directly, but the indefinite resistance of the shaft can be felt on deep palpation. Pressing the fibula against the tibia elicits pain over a fibular fracture area. The lateral surface of the distal quarter of the fibula is subcutaneous and is palpable between the lateral and anterior groups of leg muscles. It continues into the *lateral malleolus*. The *head of the fibula* is a prominent landmark.

REGIONAL SUBDIVISIONS AND MUSCLE LANDMARKS. The general surface of the leg is subdivided by natural landmarks into a bony region and three separately functioning muscle regions, the boundaries of which can be made out readily in muscular limbs free from excess fat. Their boundaries are the crest of the tibia and two vertically directed grooves on the anterolateral aspect of the leg, known as the anterior and posterior sulci. These grooves define anterior and posterior intermuscular (peroneal) septa which pass from the investing deep fascia of the leg to the anterior and lateral margins of the shaft of the fibula. These septa separate the peroneal or abductor muscle group from the flexors of the ankle and extensors of the toe in front, and the calf muscles behind.

The four subdivisions of the leg are arranged as follows (Fig. 981): the anteromesial area, which overlies the exposed shaft of the tibia; the anterolateral region, situated between the tibial crest and the anterior intermuscular septum; the lateral region, which corresponds to the area included between the two intermuscular septa; and the posterior and most extensive region, which embraces the area between the posterior intermuscular septum and the mesial border of the shaft of the tibia.

The ANTEROMESIAL AREA over the exposed shaft of the tibia is traversed over much of its extent by the *great saphenous vein* in its upward course to the mesial side of the knee and thigh. Pathologic changes dependent upon varicosities of this vessel and its tributaries localize here. The skin over this surface may appear to be in a state of chronic eczema or may be markedly indurated and adherent to the deeper tissues. Under normal conditions the great saphenous vein sometimes can be made out through the overlying skin; in a varicose state it stands out prominently and, with its tributaries, forms dilated coils beneath the skin.

The ANTEROLATERAL REGION, especially in its upper portion, is rounded into a muscle prominence by the bellies of the tibialis anterior and extensor digitorum longus muscles. The feeling of resistance in the tissues over this area is explained by the density of the overlying deep fascia investing the muscles. When the ankle is dorsiflexed actively, the fleshy part of the tibialis anterior muscle forms a prominent elevation, and the tendon can be traced distally and mesially across the dorsum of the ankle joint (p. 1069). The course of the *anterior tibial artery* coincides with the lateral margin of this muscle.

The LATERAL OR PERONEAL REGION is narrow and is limited in front and behind by the anterior and posterior peroneal sulci. In eversion of the foot the peroneal muscles applied to the lateral surface of the fibular shaft form a surface bulge, the upper part of which corresponds to the fleshy part of the peroneus longus muscle. The lower part contains the tendon of this muscle and the fleshy belly of the peroneus brevis. The *common peroneal nerve* can be rolled against the fibula behind the head and lateral to the neck of this bone. At the fibular neck the nerve divides into its two main branches, the superficial peroneal (musculocutaneous) and deep peroneal (anterior tibial). The superficial position of the common peroneal nerve and its close relationship to the fibula render it liable to injury from minor trauma or fracture of the fibular neck. Undue pressure over the nerve must be avoided.

The POSTERIOR REGION is rendered broad and prominent in its upper half, the "calf of the leg," by the two fleshy heads of the gastrocnemius muscle and by the soleus muscle. Halfway down the leg, the fleshy part of the gastrocnemius muscle merges into its tendon, which narrows rapidly. The soleus muscle remains fleshy below the middle of the leg, and its lateral margin, in contraction, projects somewhat in front of the gastrocnemius. The median groove in the upper part of the region indicates the area between the two heads of the gastrocnemius and is the surface guide to the termination of the *small (posterior) saphenous vein*. In the foot and above the ankle, this vein lies at the lateral side, but as it ascends, it gradually approaches a posterior position and occupies the median line for some distance before terminating in the popliteal vein. Below the calf of the leg, the *tendo calcaneus* stands

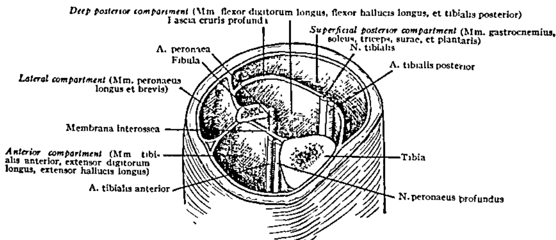


Fig. 981. CROSS SECTION THROUGH THE UPPER THIRD OF THE RIGHT LEG TO SHOW THE SUBDIVISIONS FORMED BY THE INTERMUSCULAR SEPTA.

(After Corning.)

out in bold relief, flanked on each side by a furrow, the retromalleolar groove.

DEEP FASCIA. The deep fascia of the leg closely resembles that of the thigh, with which it is continuous. It is attached above to the condyles and tuberosity of the tibia and to the head of the fibula. Its strength and density vary in different parts of the leg. Over the subcutaneous medial surface of the tibia and the lower exposed surface of the fibula the fascia is absent; over the lateral and anterior aspect of the leg it is developed strongly and is especially dense over the upper part of the tibialis anterior muscle. The fascia furnishes origin for the tibialis anterior and extensor digitorum communis muscles.

From its deep surface the fascia gives off *anterior* and *posterior intermuscular (peroneal) septa* which attach it to the corresponding borders of the fibula. The anterior septum separates the peroneal muscles from the anterior group of leg muscles, and the posterior septum demarcates the peroneal group from the muscles of the calf. Subsidiary septa pass between the individual muscles.

At the ankle the deep fascia is strengthened into ligamentous bands, the *transverse* and *cruciate ligaments* (p. 1072), which maintain the various tendons in position.

MUSCLES OF THE ANTERIOR COMPARTMENT. The anterior compartment, on transverse section, is an irregular four-sided figure, bounded anteriorly by the enveloping fascia, posteriorly by the interosseous membrane and the anterior surface of the fibula, mesially by the lateral surface of the tibia, and laterally by the anterior intermuscular septum (Fig. 981). It contains the tibialis anterior, extensor digitorum longus, extensor hallucis longus and peroneus tertius muscles, the anterior tibial vessels and the deep peroneal (anterior tibial) nerve (Fig. 982). The anterior branch of the peroneal artery enters the compartment just above the lateral malleolus.

The *tibialis anterior muscle* arises from the mesial part of the anterior compartment, from the upper two thirds of the lateral surface of the tibia and adjoining part of the interosseous membrane, and from the deep surface of the overlying deep fascia. Its tendon runs downward and mesially behind the transverse and cruciate ligaments to an insertion into the adjoining medial aspect of the first metatarsal and the first cuneiform. The muscle is separated above from the extensor digitorum longus muscle and below from the extensor hallucis longus muscle by a septum of deep fascia leading to the cellular interspace which contains the neurovascular structures of the space. This muscle dorsiflexes and inverts the foot.

The *extensor digitorum longus*, *extensor hallucis longus* and *peroneus tertius muscles* occupy the lateral part of the compartment. The extensors insert into the terminal phalanges, dorsiflex the foot at the ankle, and extend the toes. The peroneus tertius inserts into the dorsum of the base of the fifth metatarsal and dorsiflexes and everts the foot. All the muscles of this compartment are supplied by the deep peroneal (anterior tibial) nerve (L 4, 5; S 1).

MUSCLES OF THE LATERAL COMPARTMENT. The lateral compartment is the smallest and is situated between the peroneal intermuscular septa. It contains the termination of the common peroneal nerve, the superficial peroneal (musculocutaneous) nerve, and the *peroneus longus* and *brevis muscles* (Fig. 982). Both muscles arise from the lateral aspect of the fibula and run downward in the retromalleolar groove. In this groove they have a common synovial sheath, and they are maintained against the fibula by the superior retinaculum. Below the malleolus they incline forward over the lateral surface of the calcaneus. The peroneus brevis inserts into the dorsal aspect of the tuberosity of the fifth metatarsal. The tendon of the peroneus longus crosses the sole of the foot obliquely to an insertion into the lateral aspect of the base of the first metatarsal and the first cuneiform. Both muscles permit plantar flexion, abduction and eversion of the foot, and are supplied by the superficial peroneal (musculocutaneous) nerve (L 4, 5; S 1).

MUSCLES OF THE POSTERIOR COMPARTMENT. The posterior compartment is the largest, but it diminishes markedly as it approaches the ankle. Its superficial boundary is the deep fascia; the deep boundaries are formed by the posterior surface of the shaft of the tibia and fibula, the interosseous membrane and the posterior (peroneal) intermuscular septum (Fig. 981).

The muscles of this compartment operate as if in two groups. The superficial group comprises the gastrocnemius, soleus and plantaris muscles (Fig. 983), and the deep group consists of the flexor digitorum lon-

gus, flexor hallucis longus and the tibialis posterior muscles (Fig. 984). Between the two groups is a frontally placed sheet of deep fascia, about which there is a quantity of areolar tissue. This tissue space communicates with the popliteal space through the fibrous ring in the soleus muscle, allowing the reciprocal spread of infection between these two regions.

Of the SUPERFICIAL GROUP OF MUSCLES (Fig. 983), the *gastrocnemius* arises from the distal part of the femur by two heads which unite in a common tendon halfway down the leg. The broad, flat *soleus* arises from the upper posterior surfaces of the tibia and fibula and lies under cover of the gastrocnemius. It terminates in a broad aponeurosis applied to, and blended with, that of the gastrocnemius to form the *triceps surae*. Their combined tendon is the *tendo calcaneus*, or Achilles tendon, which inserts into the distal half of the posterior surface of the calcaneus. In its course the constituent bands of the tendon undergo a twisting, which varies in degree with the

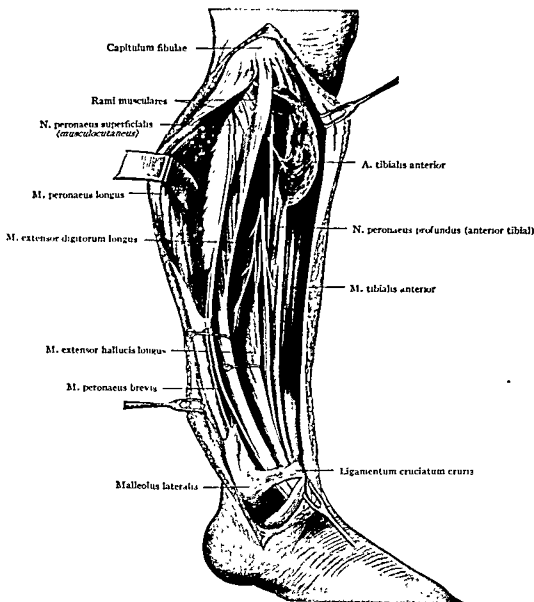


Fig. 982. STRUCTURES OF THE ANTEROLATERAL AND PROXIMAL REGIONS OF THE LEG.

Part of the anterior tibial muscle is removed to show the anterior tibial artery and deep peroneal nerve; the small hooks retract the extensor digitorum longus and the extensor hallucis longus muscles; the wide retractor is drawing aside the peroneal group of muscles.

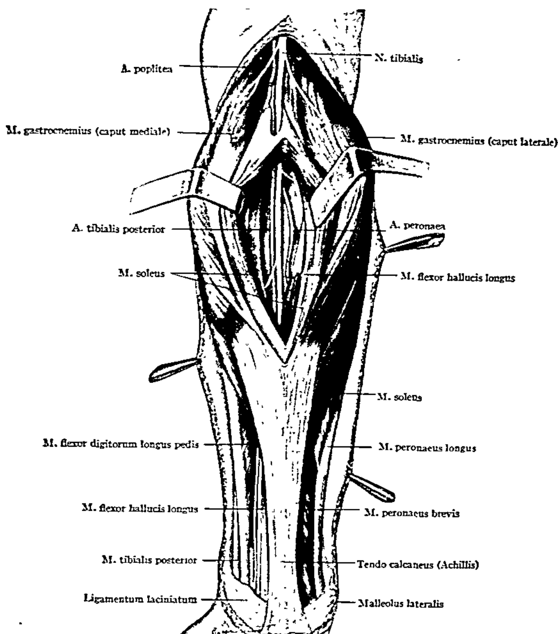


Fig. 983. SUPERFICIAL STRUCTURES IN THE POSTERIOR REGION OF THE LEG.
The bellies of the gastrocnemius are separated, and the soleus muscle is split to show the vessels and nerves in the deep muscle layers.

individual (Fig. 985). The fusion of the soleus to the gastrocnemius is the only stay which resists contracture in the gastrocnemius in its long span from the femoral condyles to the calcaneus. A small precalcaneal bursa is always present between the tendon and the upper part of the calcaneus. This bursa may become inflamed by irritation, or may be involved in gout or gonorrheal arthritis. A subcutaneous or *retrocalcaneal bursa* is sometimes present between the insertion of the calcaneal tendon and the skin, and is affected by the same lesions as those which affect the precalcaneal bursa. The stiff counter of a low shoe frequently irritates this bursa.

The *plantaris* is a muscle strip on the back of the leg applied to, and in line with, the medial border of the lateral head of the gastrocnemius. It usually ends in a long filiform tendon which is inserted into the calcaneus at the mesial margin of the tendo calcaneus. However, variations are not infrequent (Figs. 985, 985 A). Isolated rupture of the plantaris tendon may occur. All three muscles are innervated by the tibial (internal popliteal) nerve (L 4, 5; S 1, 2). They act as plantar flexors of the foot.

The gastrocnemius and plantaris also assist in flexing the leg.

The DEEP GROUP OF MUSCLES (*Fig. 984*) is demarcated from the superficial muscles by a fascial septum which extends between the fibula and the mesial border of the tibia. The *tibialis posterior* arises from the interosseous membrane and adjoining part of the tibia and fibula. Its tendon passes distally and medially in a separate space behind the laciniate ligament to a principal insertion into the navicular tuberosity. The *flexor digitorum longus* arises from the fascia on the surface of the tibialis posterior muscle and the adjoining surface of the tibia. The tendon passes mesially and distally behind the medial malleolus through a space in the laciniate ligament (p. 1072), lateral and posterior to the posterior tibial tendon. The *flexor hallucis longus* arises from the distal two thirds of the posterior surface of the fibula. At the ankle joint it passes through a separate space in the laciniate ligament, separated from the flexor digitorum longus by the tibial nerve and the posterior tibial vessels. These muscles are supplied by the tibial nerve (L 5; S 2) and act as plantar

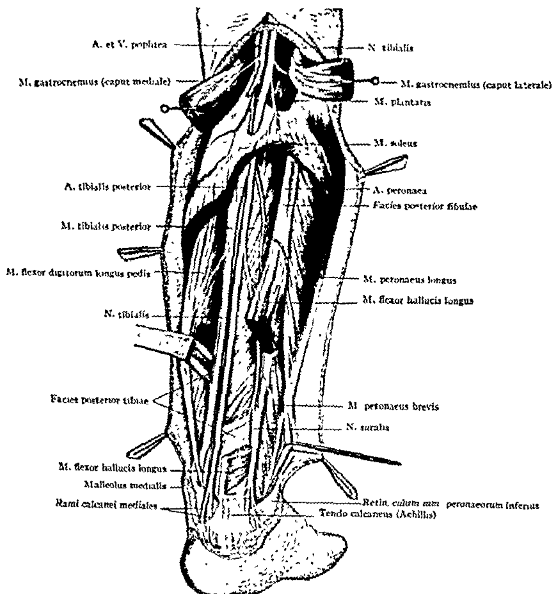


Fig. 984. VESSELS, NERVES AND DEEP MUSCULATURE OF THE POSTERIOR REGION OF THE LEG. Much of the gastrocnemius and soleus muscles has been removed.

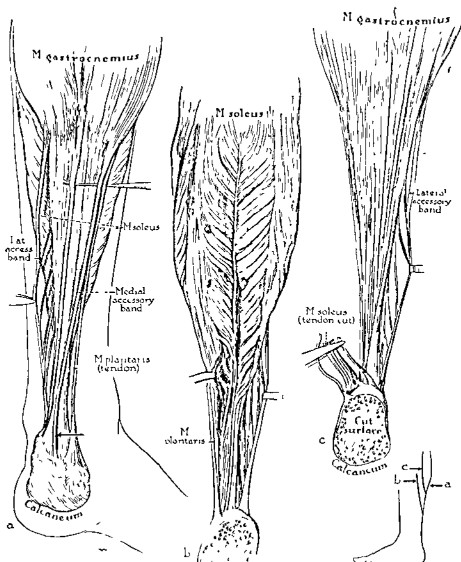


Fig. 985. STRUCTURE OF THE TENDO CALCANEUS (ACHILLIS), IN POSTERIOR AND ANTERIOR DISSECTIONS IN A LEFT LEG.

a, The calcaneal tendon in posterior view, with the soleus muscle visible beyond the margins of the tendon and of the gastrocnemius muscle. Fibers to the left of the arrow belong to the gastrocnemius; those to the right are constituents of the soleus component of the calcaneal tendon. One of the lateral accessory bands of the tendon has been retracted by forceps, and intermediate and medial tendinous bands have been lifted by a probe. The plantaris tendon remains *in situ* (see other types of attachment in Figure 986). *b*, The soleus muscle and the calcaneal tendon in anterior view (the calcaneus sectioned immediately in front of the tendinous attachment). The bipenniform structure of the tendon is demonstrated, as well as the manner in which the aponeurosis (which becomes part of the tendon) ascends toward the tibiofibular origin of the soleus. *c*, Anterior view of the part of the calcaneal tendon which is contributed by the gastrocnemius muscle; shown by removal of the soleus (fibers of insertion held by the forceps). *Inset:* level and direction for each of the figures. (From Cummins, Anson, Carr, Wright and Hauser. Surg., Gynec. & Obst., 83: 107–16, 1946.)

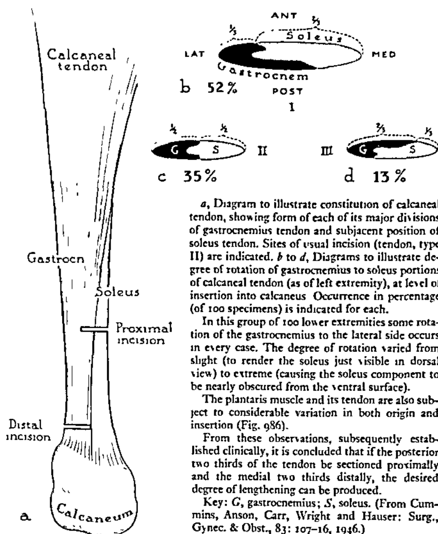
flexors of the foot. The tibialis posterior is a powerful inverter as well, and the two other muscles flex the toes.

ARTERIES. The leg receives a bountiful arterial supply from the popliteal artery through its anterior and posterior tibial branches (Figs. 982 to 984). The branches are given off just after the parent trunk has penetrated the tendinous arch of the soleus muscle. They anastomose freely, especially about the ankle and in the foot, so that circulation is adequate when one or the other main trunk is occluded. These large arteries lie close to the shafts of the bones, where they are exposed to injury by sharp fragments in cases of fracture. An embolus conveyed along the popliteal artery may lodge at its point of bifurcation and block both tibial

arteries. Should the succeeding thrombosis extend along the tibial arteries and occlude the recurrent branches, the remaining collateral channels may be insufficient to maintain circulation.

The ANTERIOR TIBIAL ARTERY arises from the popliteal artery at the lower border of the popliteus muscle (p. 1012) and passes through the upper part of the interosseous membrane into the anterior compartment of the leg (Fig. 982). The artery lies at first upon this membrane close to the neck of the fibula, but inclines medially and forward as it descends and rests against the anterior surface of the shaft of the tibia in the lower quarter of the leg. Throughout its course it is surrounded by the two interlacing venae comites, and is accompanied by the deep peroneal (anterior tibial) nerve, after that nerve has wound around the head of the fibula. Proximally, the artery lies deep between the tibialis anterior and the extensor digitorum longus muscles. In the middle of the leg the artery is located between the tibialis anterior and the extensor hallucis longus muscles. As it approaches the ankle it is crossed by the tendon of the latter muscle, and, just above the transverse ligament, is comparatively superficial. In front of the ankle the anterior tibial artery is continued into the dorsalis pedis.

The *course* of the anterior tibial artery corresponds to a line joining a point just mesial to the head of the fibula and a point at the ankle midway between the malleoli. The incision for ligation of the artery is made along this line. After the deep fascia has been divided



a, Diagram to illustrate constitution of calcaneal tendon, showing form of each of its major divisions of gastrocnemius tendon and subjacent position of soleus tendon. Sites of usual incision (tendon, type II) are indicated. *b* to *d*, Diagrams to illustrate degree of rotation of gastrocnemius to soleus portions of calcaneal tendon (as of left extremity), at level of insertion into calcaneus Occurrence in percentage (of 100 specimens) is indicated for each.

In this group of 100 lower extremities some rotation of the gastrocnemius to the lateral side occurs in every case. The degree of rotation varied from slight (to render the soleus just visible in dorsal view) to extreme (causing the soleus component to be nearly obscured from the ventral surface).

The plantaris muscle and its tendon are also subject to considerable variation in both origin and insertion (Fig. 986).

From these observations, subsequently established clinically, it is concluded that if the posterior two thirds of the tendon be sectioned proximally and the medial two thirds distally, the desired degree of lengthening can be produced.

Key: *G*, gastrocnemius; *S*, soleus. (From Cummins, Anson, Carr, Wright and Hauser: Surg., Gynec. & Obst., 83: 107–16, 1946.)

Fig. 985 A. CONSTITUTION OF THE CALCANEAL TENDON.

the tibialis anterior muscle is retracted medially, and the other muscles are retracted laterally. In its upper third the artery is exposed on the interosseous membrane; the deep peroneal nerve lies lateral to it. In the middle third the deep peroneal nerve lies anterior to it. In the distal third the artery lies on the tibia, crossed obliquely by the tendon of the extensor digitorum longus. The deep peroneal nerve is on the lateral side.

Collateral circulation is established through the anastomosis about the malleoli and the connection between the dorsalis pedis artery and the plantar arch (p. 1090).

The POSTERIOR TIBIAL ARTERY is the larger of the two terminal branches of the popliteal (Figs. 983, 984). It originates just distal to the ring in the soleus muscle and inclines medially as it descends in the posterior compartment. At its termination it lies midway between the medial malleolus and the medial tubercle of the calcaneus, where it divides into its terminal medial and lateral plantar arteries (p. 1090). In its downward course the artery lies on the deep group of posterior muscles, bound down by the fascial septum which separates these muscles from the gastrocnemius and soleus. In its upper two thirds the artery is deep; in the rest of its course it is superficial. Near its termination it lies beneath the laciniate ligament among the tendons of the deep leg muscles.

The course of the posterior tibial artery corresponds to a line extending from the center of the back of the leg, a palmbreadth below the bend of the knee, to a point at the ankle midway between the calcaneal tendon and the medial malleolus. The incision for *ligation* of the artery in its upper two thirds is not made exactly in the course of the artery, since the incision would entail an extensive division of the gastrocnemius and soleus muscles, but is made a fingerbreadth behind the medial border of the tibia. Retraction of the skin and fascia exposes the free margin of the medial head of the gastrocnemius muscle, which overlaps the origin of the soleus muscle from the medial border of the tibia. The wound is deepened through the soleus, exposing the strong fascia covering the deep muscles. This fascia is split carefully, and its lateral part is raised from the underlying muscles, exposing the posterior tibial vessels which lie on the posterior tibial muscle. In the upper third of the leg the tibial nerve lies close to the medial side of the artery and must be avoided in applying the ligature.

For a deep wound in the upper posterior part of the leg it may be necessary to make a long, straight incision in the midline of the upper leg, beginning two or three fingerbreadths below the bend of the knee. After drawing aside the small saphenous vein, the deep fascia is incised, and the interval between the two heads of the gastrocnemius muscle is brought into view. The gastrocnemius is divided vertically as far as the wound will permit. By retracting the wound margins, the deeper structures are exposed. Within this area are found the lower part of the popliteal artery, its two branches, and the origin of the peroneal artery from the posterior tibial artery. The first part of the tibial nerve is exposed.

The PERONEAL ARTERY, arising about 2.5 cm. below the bifurcation of the popliteal, is the largest branch of the posterior tibial artery (Fig. 984). It follows the medial edge of the fibula within the fibers of origin of the flexor hallucis longus, and remains in close relation with the posterior aspect of the bone and with the interosseous membrane throughout the rest of its course. Just proximal to the ankle joint it gives off a branch which pierces the interosseous membrane, and descends in front of the lateral malleolus to be distributed to the anterolateral part of the ankle and to the tarsal region. Both branches contribute to the malleolar anastomoses.

The incision for ligation is made over the posteromesial edge of the fibula. After the edge of the soleus muscle has been drawn medially and the fibers of the flexor hallucis longus muscle have been divided, the artery is found at the junction of the medial edge of the fibula and the interosseous membrane.

VEINS. The veins of the leg are arranged in two groups, deep and superficial. The deep veins lie beneath the deep fascia and accompany the arteries in the lower extremity. Each of the arteries below the popliteal has two accompanying veins, while the femoral and popliteal arteries have but one.

The *great* (*internal*) *saphenous vein* (Figs. 990, 994) begins in the foot and ankle and ascends superficially on the medial aspect of the tibia. It passes along the posterior border of the medial tibial condyle and thence up the thigh to empty into the femoral vein at the saphenous opening (Fig. 902). Under normal

M. PLANTARIS
TYPES OF TENDINOUS INSERTION
585 SPECIMENS

Fig. 986. TENDON OF THE PLANTARIS MUSCLE; MAJOR TYPES OF INSERTION, WITH PERCENTAGE OCCURRENCE OF EACH IN 585 EXTREMITIES.

a, Attachment to the calcaneus as a part of the calcaneal tendon (degree of separateness being variable). *b*, A broader insertion, fan-shaped, prolonged forward on the calcaneus toward, or to, the origin of the abductor hallucis. *c*, An even more expansive implantation, employing the laciniate ligament. *d*, Insertion separately into the calcaneal bone crosswise between the *tendo calcaneus* and the tibia. *e*, Elongate attachment to the anterior surface and medial border of the calcaneal tendon, usually by numerous bands, with occasional prolongation forward on the superior surface of the body of the calcaneus. *f* to *h*, Insertion not only into the calcaneus anterior to the combined tendon of the gastrocnemius and soleus, but also posteriorly to cover part (*f*) or all (*g*, *h*) of the *tendo calcaneus* on the superficial aspect of its distal extremity. (Redrawn with augmented data, from Cummins, Anson, Carr, Wright and Hauser: Surg., Gynec. & Obst., 83: 107–16, 1946.)

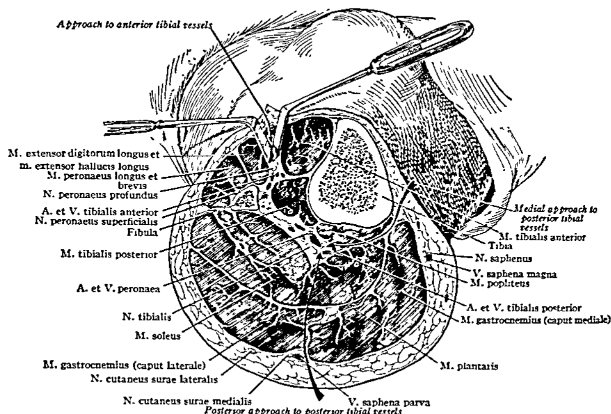


Fig. 987. CROSS SECTION THROUGH THE UPPER PART OF THE RIGHT LEG TO SHOW THE APPROACH TO THE ANTERIOR AND POSTERIOR TIBIAL VESSELS.

The anterior arrow indicates the approach to the anterior tibial vessels; the medially placed arrow marks the medial approach to the posterior tibial vessels; the posterior arrow indicates the posterior approach to the posterior tibial vessels.

conditions the vein cannot be distinguished under the skin, but, when markedly varicose, the vein and its tributaries stand out prominently. It communicates in the leg with the deep veins accompanying the tibial and peroneal arteries and with the small saphenous vein (Fig. 997). From the leg down it is associated with the saphenous nerve (L 3, 4). The *small (external) saphenous vein* (Fig. 999) begins at the ankle behind the lateral malleolus and ascends at first along the lateral aspect of the leg. It gradually approaches its posterior aspect and follows the median line for a short distance before terminating in the popliteal vein. Through its superficial branches and by its deep connection with the venae comites, it anastomoses with the great saphenous vein. It is accompanied by the sural (short saphenous) nerve.

LARGE NERVES. Each of the three muscle compartments of the leg (Figs. 981, 987, 988) has its own nerve as well as arterial trunk. The *tibial (internal popliteal) nerve* (L 4, 5; S 1, 2, 3) passes distally through the posterior compartment in close relation to the posterior tibial vessels. It lies at first on their medial side, but lower down crosses them superficially to lie on their lateral aspect at the ankle. It supplies all the muscles of the posterior compartment, and divides under the laciniate (internal annular) ligament into lateral and medial plantar branches (p. 1090).

Within the lateral or peroneal compartment opposite the neck of the fibula, the common peroneal nerve divides into its two terminals, the superficial and deep peroneal nerves. The *superficial peroneal (musculocutaneous) nerve* (L 4, 5; S 1, 2) passes forward between the fibula and the peroneus longus muscle and descends immediately behind the anterior intermuscular (peroneal) septum, where it supplies the peroneus longus and brevis muscles. At the junction of the middle and lower thirds of the septum it pierces the deep fascia and passes downward and inward across the extensor tendons. The *deep peroneal (anterior tibial) nerve* (L 4, 5; S 1) is derived from the common peroneal nerve on the lateral aspect of the fibular neck, and descends through the anterior compartment in company with the

anterior tibial artery. It innervates all the muscles of the anterior compartment and terminates in front of the ankle joint by dividing into medial and lateral branches.

SHAFTS OF THE FIBULA AND TIBIA. The fibula and tibia are united at their extremities by the proximal and distal tibiofibular joints and between them by the interosseous ligament (Fig. 981). The *interosseous ligament* is a strong fibrous membrane formed by crisscrossing fibers which transmit indirect violence from the tibia to the fibula.

The slender *fibula* reinforces the tibia and enables it to withstand extreme bending and twisting; without fibular support, tibial fracture would occur much more frequently. The fibula is an exception to the general rule that the epiphysis toward which the nutrient artery is directed is the last to appear and the first to unite with the shaft. In the fibula the nutrient artery is directed downward, yet growth takes place at the lower epiphysis, which is the first of the fibular epiphyses to appear and the first to unite. The upper three fourths of the fibula furnish extensive muscle attachments. The lower extremity of the fibula, the lateral malleolus, enters into the formation of the ankle joint and, with the tibia, maintains a strong mortise for the reception of the talus. Occasionally the fibula is congenitally absent, so that the tibia is devoid of support and the ankle joint lacks normal stability.

The *tibia* is much the stronger and more important bone, for it alone articulates with the femur and transmits the body weight through the ankle to the foot. The shaft of the tibia is composed of a strong shell of compact bone enclosing a central medullary cavity. Its sturdy anterior margin or crest is a thickened part of the compact cortex and is most dense in the middle of the shaft. Because of its strength and accessibility, grafts commonly are taken from it for bony transplants. Near each articular extremity the outer shell diminishes considerably in thickness and encloses a quantity of cancellous tissue which extends upward and downward a considerable distance from the articular margin. The tibia

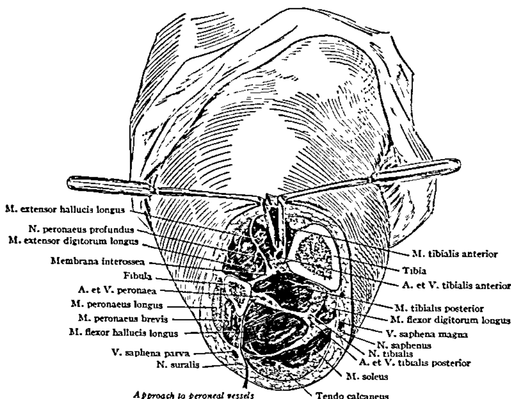


Fig. 988. CROSS SECTION THROUGH THE MIDDLE PORTION OF THE LEG.

The incision is widened by retraction to indicate the approach to the anterior tibial vessels; the arrow indicates the path of approach to the peroneal vessels.

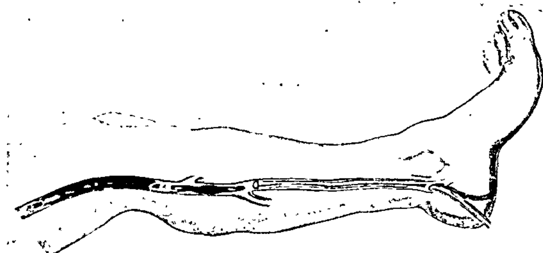


Fig. 989. FEMORAL AND POSTERIOR TIBIAL ARTERY EMBOLECTOMY.
The embolus is "packed" in the artery above the bifurcation of the popliteal, necessitating two arteriotomy wounds to remove the embolus completely from the lower femoral and popliteal artery. The distal propagating thrombus was removed both from above and also by catheterizing the posterior tibial artery and flushing it out from below with heparin solution. (From Dye, Olwin, Javid and Julian: Arch. Surg., 70: 715–22, 1955.)

is not straight, but is convex medially in the upper half and laterally in the lower half. These curves are important to maintain the reduction of fractures. The mesial and lateral twisting of the tibial shaft in congenital clubfoot or in paralytic deformities so disturbs the alignment of the foot that corrective osteotomies may be required.

The nutrient foramen of the tibia is the largest in the skeleton; it lies on the posterior surface of the upper third of the bone. The nutrient canal runs a long downward course in the compact bone before opening into the medullary cavity. Fracture of the tibia through the nutrient canal predisposes to nonunion.

In addition to its susceptibility to all varieties of direct injury, the tibia is especially liable to certain forms of disease, one of the most devastating of which is *acute osteomyelitis*. The tibial shaft is often the site of a *syphilitic lesion*, which manifests itself as a chronic osteitis and periostitis, and may lead to much thickening. The nodes of localized periosteal elevation make the smooth surface of the tibial shaft uneven. In the "saber shin" of hereditary syphilis the tibia is thickened, roughened, and flattened from side to side so that it presents a marked anterior convexity. The tibia, especially at its extremities, occasionally is the seat of local inflammatory disease which terminates in the formation of a central abscess (*Brodie abscess*).

Surgical Considerations

POSTERIOR TIBIAL EMBOLECTOMY. The need for a positive surgical approach to arterial emboli, regardless of the age of the patient or position of the clot, has been emphasized. Such an obstruction below the popliteal space has been difficult to remove, but catheterization of the posterior tibial artery from below offers some hope (Fig. 989).

VARICOSE VEINS. Varicose veins are characterized by dilatation and loss of the normal valvular mechanism. The consequent stagnation and back-pressure of venous blood cause fibrosis, overstretching, elongation and sacculation of the walls.

The great frequency of varicosity in the saphenous veins is considered to be caused by the high back-pressure within these vessels, and is attributed to the long-maintained erect posture and the tall column of blood from the legs to the heart. The great saphenous vein may be regarded as the lower part of a tube, the upper part of which coincides with the opening of the inferior vena cava into the heart. It differs from an open tube in that normally it is segmented by a series of bicuspid valves, each pair of which supports the column of blood immediately above, and removes the weight from the column below. Movement upward is mainly brought about by the muscular action of the leg, there being little venous pressure for this

purpose. Much of the blood probably traverses the *communicating or perforating veins of the leg* (Figs. 997 to 1001) to the femoral system, where support from surrounding tissue and muscular action is more effective in forcing blood upward.

The factors considered important in the development of saphenous varices are a hereditary tendency; the undue strain of prolonged standing, as by waiters, laundresses, streetcar conductors, store clerks and others; the increased venous hypertension of pregnancy, due to the pressure of the enlarged uterus on the iliac veins, and the increased volume of venous blood flowing from the hypogastric vein; and, finally, phlebitis. Varicosities may be present in young adult life, and by middle age a high percentage of people are so afflicted to varying degrees. The early symptoms of progressive venous insufficiency are a tired, heavy sensation in the legs and the unsightly, prominent veins. The long or short saphenous venous system, or both, may be involved. As a result of the varicosities and poor nutrition of the parts consequent to the stagnation of blood, the skin over the lower and medial parts of the leg may develop chronic eczema or become markedly indurated, deeply pigmented, and adherent to the deeper tissues. Varicose ulcers often develop in these areas and are difficult to heal.

T. T. Meyers and R. Stanton Sherman have contributed extensively to the subject of varicose veins, and much of the following has been taken from their publications.*

Varicose veins often are large near the skin and easily visible, while in other cases they are buried deep in subcutaneous tissue. The compression test (Fig. 990), which should always be done, outlines the course of the varices and indicates roughly whether the valves are incompetent.

The retrograde-filling test, or modified Brodie-Trendelenburg test (Figs. 991, 992), is used after the compression test to verify the impression of incompetency of the valves of the great and small saphenous veins. The results of these tests are accurate, but frequent use and skill are necessary to perform them properly.

Treatment is now mainly by stripping out the varicosed segments, and the indications for this operation are (1) large varicosities; (2) stasis changes such as dermatitis, ulcerations, pigmentation and chronic induration; (3) a history of single or recurrent attacks of superficial thrombophlebitis; (4) incompetence of both deep and superficial veins with venous stasis in which the superficial veins are a definite factor; and (5) need for a prophylactic procedure.

Contraindications to the stripping operation may be classed as temporary and permanent or absolute. The temporary contraindications are (1) recent deep thrombophlebitis or acute superficial thrombophlebitis, (2) weeping dermatitis elsewhere in the body, (3) suppurative disease anywhere in the body, (4) acute and subacute stasis cellulitis of the leg, (5) pregnancy, (6) poor general condition, (7) obesity, (8) severe secondary anemia with hemoglobin of less than 10 gm. per 100 ml. of blood, (9) recent extensive sclerosing therapy, (10) early asymptomatic varicosities, (11) main complaint due to other diseases of the lower extremity, and (12) uncontrolled metabolic disease. Permanent contraindications are (1) definite arterial deficiency of the lower extremity, (2) normal but prominent-appearing veins, (3) asymptomatic varicosities occurring during advanced age, (4) severe deep venous

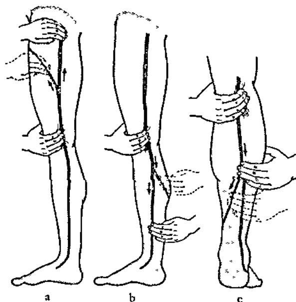


Fig. 990. VARICOSE VEINS. THE COMPRESSION TEST.

a, Method of percussion to demonstrate an incompetent great saphenous vein at the fossa ovalis. *b*, Method of following course of the great saphenous vein. *c*, Percussion of an incompetent lesser saphenous vein. (From Meyers: S. Clin. North America, 35: 1-27, 1955.)

* Meyers, T. T.: S. Clin. North America, 35: 1147-73, Aug., 1955. R. S. Sherman: Ann. Surg., 130: 218-32, 1949.



Fig. 991. VARICOSE VEINS. RETROGRADE-FILLING TEST (MODIFIED BRODIE-TRENDELENBURG), SHOWING *INCOMPETENCY OF GREAT AND SMALL SAPHENOUS VEINS.*

a, *b*, Patient standing; both saphenous veins filled. *c*, Veins emptied; tourniquet applied; thumb over small saphenous vein. *d*, *e*, Patient standing; tourniquet occludes great saphenous vein; thumb occludes small saphenous vein. *f*, *g*, Tourniquet is released after 15 seconds of standing. Prompt filling of veins proves incompetency of great saphenous vein. *h*, Veins emptied again; tourniquet and thumb applied, *i*, *j*, Patient standing; thumb removed in 15 seconds. Filling of veins proves incompetency of small saphenous vein. (From Meyers: S. Clin. North America, 35: 1–27, 1955.)

insufficiency when mild varicosities do not appear to be a factor, (5) chronic lymphedema with minimal varicosities and also severe varicosities unless the patient understands that improvement of the lymphedema cannot be expected, and (6) severe constitutional disease with poor prognosis.

After deep thrombophlebitis a period of at least a year should elapse before stripping procedures are in order. In that time deep collateral channels will be formed or deep veins reopened. Acute superficial thrombophlebitis should be quieted down by elevation of the extremity and warm packs for three days or longer before the stripping procedure is begun. Experience has shown that during pregnancy varicosities can usually be controlled with elastic support, rest and elevation of the ex-

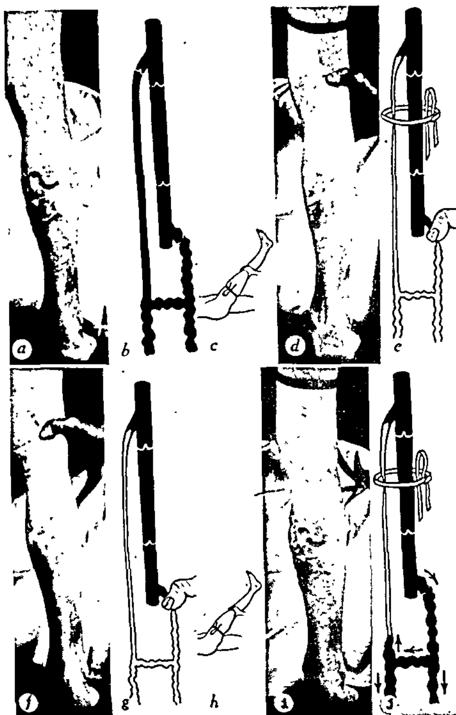


Fig. 992. VARICOSE VEINS. (MODIFIED BRODIE-TRENDELENBURG.) SHOWING COMPETENCY OF THE GREAT SAPHENOUS VEIN AND INCOMPETENCY OF THE SMALL SAPHENOUS VEIN.

a, *b*, Patient standing; both systems are filled. *c*, Veins emptied; tourniquet applied; thumb over small saphenous vein. *d*, *e*, Patient standing; tourniquet occludes great saphenous vein; thumb occludes small saphenous vein. *f*, *g*, Tourniquet released after 15 seconds of standing. No filling of veins proves competency of great saphenous veins. *h*, Veins emptied again. *i*,*j*, Patient standing; thumb removed after 15 seconds of standing. Filling of veins indicates incompetency of small saphenous vein. (From Meyers: S. Clin. North America, 35: 1-27, 1955.)

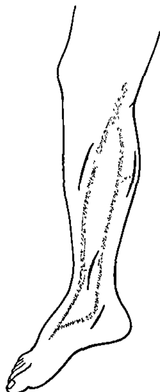


Fig. 993. VARICOSE VEINS. INCISION OVER INCOMPETENT PERFORATING VEINS.

(From Meyers: S. Clin. North America, 35: 1–27, 1955.)

tremity. The stripping operation can be done three months after labor.

Before operation the main channels of varicosities and tributaries should be marked out, and special emphasis is placed on the possibility that an incompetent double system may be present. Incompetent perforating veins must be located (Figs. 991, 992, 996 to 1002) and marked, and the surgeon, not the assistant, should do the marking.

The treatment procedure used is that of an extensive operation for complete removal of the main channel and the incomplete tributaries. In some cases incompetency is only in the upper portion of the main channel of the great saphenous vein, with a large tributary also affected, and the remaining portion of the great saphenous vein from the thigh to the foot is competent. If the main channel of the great saphenous vein only is removed from foot to groin, the large, important, incompetent tributaries then will be a nidus for future or persistent varicosities. In all cases when the vein is so tortuous that the stripper cannot be passed in either direction the tortuous vein should be removed by direct dissection or evulsion. For a competent main channel of the great saphenous vein with an incompetent superficial lateral branch, the incompetent vein should be removed together with the main channel even though it is competent. The great saphenous vein may be incompetent in the upper third of the thigh only, and this may be associated with incompetency of the superficial medial cutaneous vein and varicosities connected with dilated labial veins. Varicosities of the superficial medial cutaneous vein are most frequently aggravated by repeated pregnancies. It should be removed completely along the main channel, with direct dissection of the vein going to the labial veins and direct removal of veins in the labia majoris.

The more extensively the venous system associated with varicose veins is removed and interrupted (Figs. 994, 995), the longer the period before varicosities develop in another superficial system. The ligation of the main vein and tributaries at the saphenofemoral junction must be carefully done through good exposure and painstaking dissection (Fig. 1003). Marked variation in the tributary pattern is common (Fig. 902).

PERFORATING VEINS OF THE LEG AND THIGH. These veins connect the two saphenous systems with the deep veins of the leg. They have been extensively studied by Sherman because of the role incompetent valves in these veins play in the failures of the ligation and stripping treatment of varicose veins.

The distribution of perforator veins connecting the two saphenous systems with the deep veins in the leg varies somewhat, but if adjustments are made for differences in height, a remarkable constancy in their placement is observed in both the leg and the thigh (Figs. 996 to 999). The surgical dissections performed by Sherman revealed that thigh perforators are not as frequently incompetent as was previously believed, and that leg perforators are numerous, are frequently incompetent and thus much more responsible than the former for unsatisfactory varicose vein therapy.

The successful treatment of incompetent perforator veins depends upon a full understanding of the patterns shown in the figures, and especially of the characteristics of the saphenous tributaries *B*, *B'*, *B''*, *B'''*, the mid-Hunter canal perforator system and the genicular plexus of Figures 996 to 999, and the anatomic distribution of perforators in the leg (Figs. 1000 to 1002).

Ligation of incompetent perforator veins beneath the deep fascia of the thigh (Fig. 996), and the medial (Fig. 1000) and lateral (Fig. 1001) aspect of the leg, and of the calf (Fig. 1002), *to completely efface reflux of blood* has been emphasized by Sherman as an important step in the eradication of varicose veins and ulcers. Lofgren, Myers and Webb, Jr., conclude that the essentials of adequate surgical treatment of varicose veins include (1) adequate ligation above at the saphenofemoral (Fig. 1003) or saphenopopliteal juncture; (2) thorough removal of all incompetent superficial veins below, down to the dorsum, or lateral aspect of the foot, by stripping and dissection; and (3) individual ligation and resection of all incompetent perforators present.

SURGICAL APPROACHES TO THE TIBIA AND FIBULA. The *approach to the tibia* for exploration or resection is along the exposed medial surface of the bone. Care is taken to avoid the saphenous nerve and the great saphenous vein lying in front of the medial malleolus. The incisions which *expose the fibula* are planned to avoid injury to the superficial (musculocutaneous) peroneal nerve. The approach to the proximal and middle thirds is made through an incision along the line of the posterior intermuscular (peroneal) septum. In the upper third of the shaft the incision is developed between the adjoining borders of the soleus and peroneus longus muscles. Injury to the common peroneal (external popliteal) nerve, where it winds around the neck of the fibula, must be avoided. In the middle third of the shaft a lateral incision is made through the interval between the peroneus longus and flexor hallucis longus; the latter muscle projects laterally beyond the lateral margin of the soleus. The incision for the distal third of the shaft is made just behind the anterior

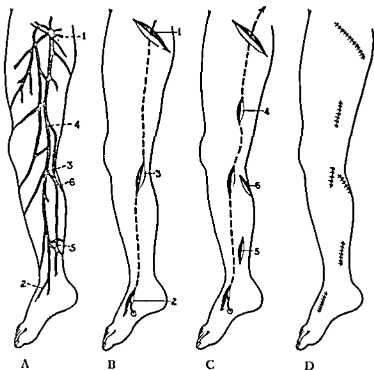


Fig. 994. VARICOSE VEINS. GREAT SAPHENOUS VEIN AND ITS TRIBUTARIES.

A, 1 to 6 show usual sites of incisions needed for tributaries. The groin incision parallels the inguinal fold and should extend 5 cm. lateral to the femoral artery and 13 cm. medial and downward, so that all vessels in the region of the saphenofemoral junction can be ligated except the femoral vein and artery. The most common sites of important tributaries are positions 1, 2 and 3 in *A*, and the incisions to expose these are shown in *B*. Incision 4 in *C*, on the medial surface of the distal third of the thigh, is frequently necessary to pick up a commonly enlarged tributary coursing down over or medial to the knee. This same tributary often can be isolated again at 6 in *C*. Other incisions, in *C* and *D*, may be needed to strip or excise tortuous veins. If a vein is incompetent, it must be removed by whatever means are necessary. (From Meyers: S. Clin. North America, 35: 1-27, 1955.)

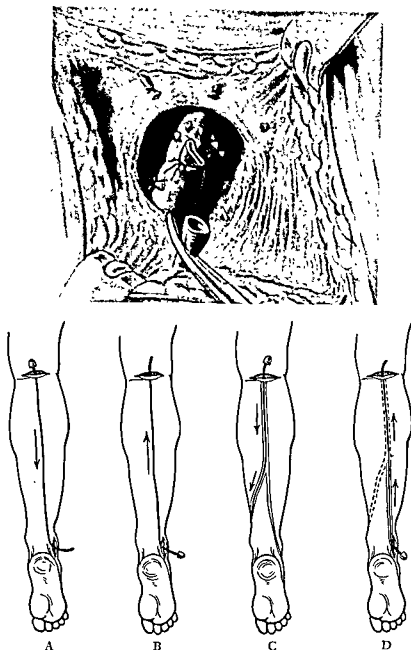


Fig. 995. VARICOSE VEINS.

Upper, Ligation of vessels near saphenofemoral juncture. The saphenous vein should be ligated flush with the femoral vein. *Lower*, Incisions for stripping small saphenous vein. *A*, *B*, Stripper may be passed either upward or downward in the small saphenous vein. *C*, Stripper passed into an important medial tributary. *D*, In the remaining portion of the small saphenous vein the stripper is passed upward. (From Meyers: S. Clin. North America, 35: 1-27, 1955.)

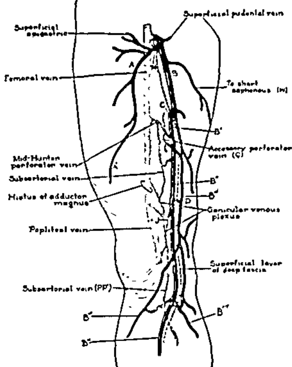


Fig. 996.

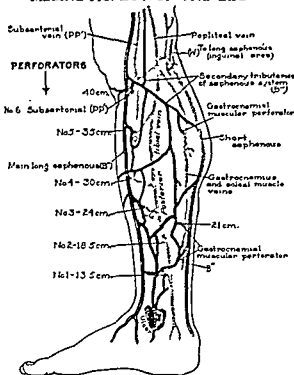


Fig. 997.

Fig. 996. VARICOSE VEINS. VEINS SUPERFICIAL AND DEEP TO THE FASCIA LATA ON THE MEDIAL ASPECT OF THE THIGH.

Showing the saphenous as *A*, *A'* and *B*, *B'*, *B"*, *B'"*. Veins *A*, *A'*, *B* lie superficial to the deep fascia, whereas distal to *C*, veins *B'*, *B"* lie beneath the superficial layer of the deep fascia. *B'"* emerges from beneath the deep fascia at *D*. The constant perforator vein midlength in the adductor (Hunter's) canal connects the main saphenous vein *B'* with the femoral vein. The genicular venous plexus brings the femoral and popliteal veins into communication with the subsartorial vein. The subsartorial vein established connections with the main long saphenous vein *B"* in the thigh and continues distally in the leg to make connections with *B"*, *B'"* and posterior tibial vein. Accessory perforator vein *Q* emerges into the superficial fascia without making direct connections with the main saphenous stem *B* , *B"*. Perforator vein *J* makes direct connection between main saphenous stem *B"* and the subsartorial vein.

Line *M* illustrates the danger of mistaking superficial vein *A* for the main long saphenous vein in patients who possess double long saphenous veins. (From Sherman: Ann. Surg., 130: 218–32, 1949.)

Fig. 997. VARICOSE VEINS. VEINS OF SUPERFICIAL AND DEEP LEVELS ON THE MEDIAL ASPECT OF THE LEG.

Showing the saphenous systems as *B"*, *B'"* and short saphenous vein The secondary saphenous tributaries *B'"* are black, to indicate their placement within the superficial fascia.

Perforator veins 3, 4 and 5 connect the posterior tibial vein with the main long saphenous vein *B"*. Perforator veins 1 and 2 connect the posterior tibial vein with secondary saphenous veins *B'"*. Perforator no. 6 connects the posterior tibial and subsartorial veins with veins *B"* and *B'"*. Accessory perforator vein *Q* emerges into the superficial fascia without making direct connections with vein *B"*.

The lightest crosshatching indicates veins situated beneath the traditional deep fascia. The medium-weight crosshatching (vein *B"* and lower part of short saphenous vein) depicts veins lying between the extension of the deep fascia of the thigh and the traditional deep fascia.

Measurements are made from the sole of the foot. (From Sherman: Ann. Surg., 130: 218–32, 1949.)

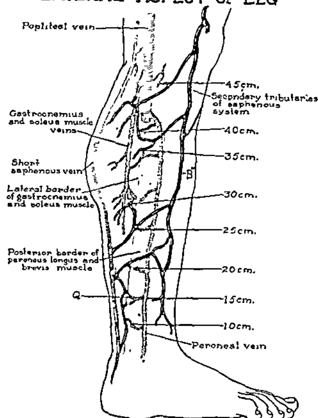


Fig. 998.

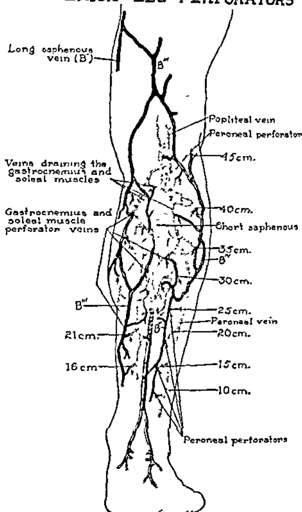


Fig. 999.

Fig. 998. VARICOSE VEINS. SUPERFICIAL AND DEEP INTERMUSCULAR VEINS AND THEIR PERFORATING INTERCONNECTIONS, *VIEWED FROM THE LATERAL ASPECT OF THE LEG.*

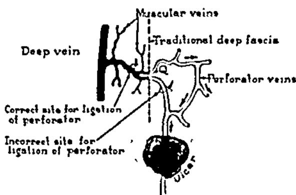
Showing perforator veins situated in the intermuscular septum between the gastrocnemius and soleus muscles, on the one hand, and peroneal muscles on the other. The perforator veins connect the peroneal vein with secondary saphenous tributaries B'''. A perforator vein (L) is depicted as emerging through the lateral border of the gastrocnemius or soleus muscles. Connections between the perforator and muscular veins are indicated. Accessory perforator vein Q emerges to connect with secondary saphenous tributary B''' at a different site than a companion perforator vein.

Measurements taken from the sole of the foot. (From Sherman: Ann. Surg., 130: 218-32, 1949.)

Fig. 999. VARICOSE VEINS. PERFORATING VEINS WHICH CONNECT THE SAPHENOUS VEINS AND ITS TRIBUTARIES WITH VESSELS OF MUSCULAR LEVEL. VIEWED FROM THE POSTERIOR ASPECT.

Showing sites of perforator veins which connect the short saphenous vein and secondary saphenous tributaries B''' with muscular veins draining the gastrocnemius and soleus muscles. In general, there are 4 longitudinal lines of perforators. Two of these are within 2 cm. of either side of the midline, and the other lines are 3 or more cm. lateral or medial to the midline. There are usually 4 or more perforators in each of the 3 medial lines and only one or 2 in the lateral longitudinal line. In the latter group the absence of perforators is compensated for by drainage through the peroneal perforator veins. Perforating veins indicated at 16 and 21 cm. might be confused with perforator no 1 or 2, as shown in Fig. 997.

Arrows indicate site of perforators. Measurements taken from the sole of the foot. (From Sherman: Ann. Surg., 130: 218-32, 1949)



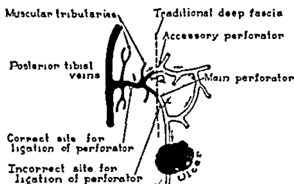


Fig. 1000. VARICOSE VEINS. METHOD OF TREATING INCOMPETENT PERFORATING VEINS ON THE MEDIAL ASPECT OF THE LEG.

Left, Demonstrating the method of treating incompetent perforator veins. Two such vessels are shown emerging through a single fascial opening. If ligation were performed at the indicated "incorrect site," the reflux of blood would route itself through the accessory perforator *Q* vein, as shown by the arrows. The ligation must be made deep beneath the fascia at the point noted as the "correct site for ligation of the perforator." *Right*, Illustrating method of treating an incompetent perforating vein on the medial aspect of the leg in a case which differs from the preceding in the occurrence of an accessory perforator, at *Q*, which emerges through a separate opening in the fascia lata. Were the ligation not performed at the indicated "correct site," the reflux of blood would route itself through the accessory perforator *Q* vein, as shown by the arrows. (From Sherman: Ann. Surg., 130: 218-32, 1949.)

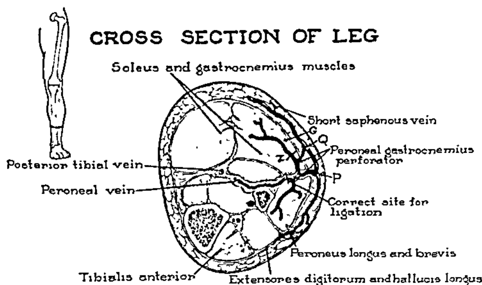


Fig. 1001. VARICOSE VEINS. METHOD OF TREATING INCOMPETENT PERFORATING VEINS ON THE LATERAL ASPECT OF THE LEG; SHOWN BY CROSS-SECTION.

The perforator is situated in the intermuscular septum between the gastrocnemius and soleus muscles, on the one hand, and the peroneus longus and brevis, on the other. In order to prevent the reflux flow of blood through either the perforator *P* vein or the accessory perforator *Q* vein, the ligation must be made deep at the point noted as the "correct site for ligation." The connections between the main perforator vein, the accessory perforator *Q* vein, and the *G* veins draining the gastrocnemius and soleus are indicated. The muscular *G* vein must also be ligated at point *Z*. (From Sherman: Ann. Surg, 130: 218-32, 1949.)

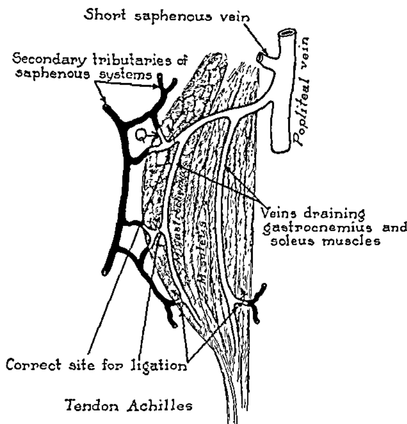


Fig. 1002. VARICOSE VEINS. METHOD OF TREATING INCOMPETENT PERFORATING VEINS IN THE CALF OF THE *LEG; SHOWN IN A LONGITUDINAL SECTION.*

In order to prevent reflux of blood through the accessory *Q* vein, the ligation must be deep within the muscle at the point designated as "correct site for ligation." (From Sherman: Ann. Surg., 130: 218-32, 1949.)

intermuscular septum in the interval between the peroneus brevis and tertius muscles.

AMPUTATION THROUGH THE LEG. Amputation through the leg may be required for a variety of conditions: irremediable tuberculosis of the ankle, gangrene of the lower part of the limb, or severe injury in which the bones and soft tissues are damaged hopelessly.

Pirogoff's and Syme's amputations just above the ankle joint may be classified as amputations through the *lower third* of the leg, but they are discussed topographically as amputations through the ankle (p. 1085).

The ideal level of amputation below the knee is 5 to 7 inches below the joint, many surgeons preferring a 5- to 5½-inch point (Fig. 1004). *A long anterior and a short posterior flap* throw the suture line well behind the stump end. If the blood supply is reasonably good, *a posterior flap of fascia is formed sufficiently long to fold around the lower end of the stump and meet upon the front of the limb. The fibula is sawed 2.5 cm.* shorter than the tibia, and the crest of the tibia is well bevelled. In selected cases, because of lack of blood supply, lateral flaps of equal length may be fashioned, and are sometimes preferable to the long anterior flap method.

All amputations through the *upper third of the leg are above the site of election. They* afford less leverage than amputations at a lower level, but often can be provided with a good prosthesis allowing active knee motion. The fibula is commonly excised in these short leg amputations, because its lower end tends to become more prominent and to protrude at an angle from the tibia. Removal of the fibula is *advisable in all amputations in the upper third* of the leg.

At the level of the upper third of the leg there are large posterior and antero-external muscle masses consisting mainly of the gastrocnemius and soleus and the tibialis ante-

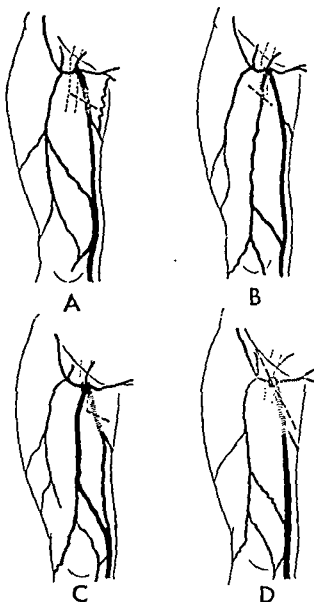


Fig. 1003. VARICOSE VEINS. INADEQUATE LIGATION OF LONG SAPHENOUS VEIN AT THE GROIN AS A CAUSE OF EARLY RECURRENT VARICOSE VEINS. FINDINGS ON RE-EXPLORATION OF THE GROIN IN 488 EXTREMITIES.

A, Ligation too low, leaving a long saphenous stump to which important tributaries were attached: 48 per cent of extremities. *B*, Greater saphenous vein itself not ligated: 8 per cent. *C*, Persistent accessory saphenous vein as the chief mechanism for recurrence: 4 per cent. *D*, Adequate ligation of great saphenous and groin tributaries: 40 per cent. (From Lofgren, Myers and Webb, Jr.: Surg., Gynec. & Obst., 102: 729-36, 1956.)

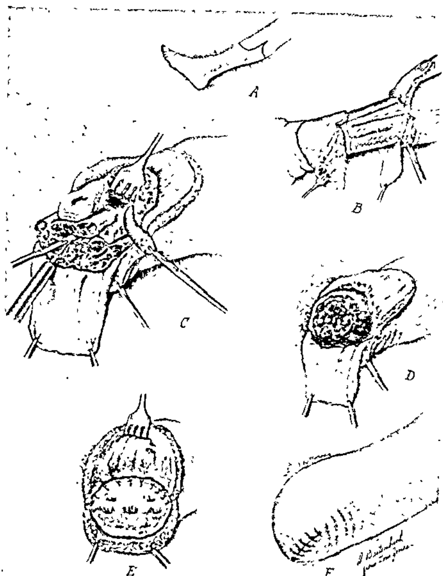


Fig. 1004. LEG AMPUTATION AT OPTIMAL LEVEL.

A, Lines of incision for long anterior and short posterior skin flaps. *B*, Anterior skin and fascia flap reflected; long posterior fascial flap cut and separated from posterior skin flap. This should not be done on patients having poor circulation. *C*, Crest of tibia cut obliquely and remainder of bone transversely; periosteum cut from bone end. Many surgeons now do not excise the periosteum, but cut it cleanly at the saw line. Fibula sectioned 2 to 3 cm. shorter than tibia. Nerves gently pulled down and shortened. *D*, Muscles grouped about ends of bone. *E*, Posterior fascial flap sutured over muscles and bone ends. *F*, Skin flaps closed. (From Orr: Operations of General Surgery.)

rior and peroneus longus. With the exception of the gastrocnemius and plantaris, the muscles at this level are fixed to the bones and deep fascia, and cannot retract when divided. The operative treatment of an amputation in the upper third is the same as that in the middle, save that the fibula is removed in the former instance. The tibialis anterior muscle is cut long enough to swing across the bevelled crest of the tibia. The other muscles in the anterior group are cut to retract to the saw-line, and the calf muscles are severed so that their posterior surfaces retract above the saw-line. The muscle bellies slope gradually from this level downward and forward to the saw line.

Fractures of the Shafts of the Tibia and Fibula. Fracture of the leg bones (Figs. 1005, 1006) presents a problem different from that in fracture of the forearm, for the leg has no rotary motion to preserve. Any angulation of its bones may result in a change in the axis of weight-bearing, which throws an undue stress upon the ankle and knee joints. Fracture

of one bone rarely results in deformity, since overriding of the fragments is opposed by the splinting effect of the intact bone. If both bones are broken, the advantages of easy palpation and access are overcome by the tendency to compounding.

Both bones of the leg may be broken by the *direct violence* of a severe blow or a crushing injury at any level between their upper and lower extremities. The site of break coincides with that of the injury, and both bones are broken at the same level. Fractures caused in this fashion usually are transverse and often are comminuted. As a rule, they are not accompanied by much displacement. If displacement does take place, the upper tibial fragment usually is thrown forward, and sometimes pierces the skin. The lower fragment rides to the outer side. Overriding and displacement usually are the result of muscle action; therefore fractures should be immobilized as quickly as possible to obviate deformity from muscle spasm. When only the tibia is broken and the line of fracture is transverse, there may be little recognizable displacement. If the finger is carried along the crest of the bone, the line of fracture may be located by a surface irregularity and by point tenderness over the site of the lesion.

Fractures frequently are caused by the *indirect violence* of a bending strain or powerful torsion. When the leg is bent forcibly, as when the foot and ankle are fixed and the body falls, the site of the tibial fracture usually is at the junction of the middle and lower thirds, where the bone is most slender. When the tibia breaks, the fibula bends and, if the force is exhausted rapidly, may not fracture. If the acting force is excessive and fracture of both bones occurs, the fibular fracture generally does not occur at the same level, but at a point higher up. Tibial fracture most often is oblique, and the pointed extremity of the upper fragment, which is superficial, may pierce the skin. An open fracture may occur at the time of injury, but frequently a fracture primarily simple is made an open fracture by careless handling or not protecting the fracture im-

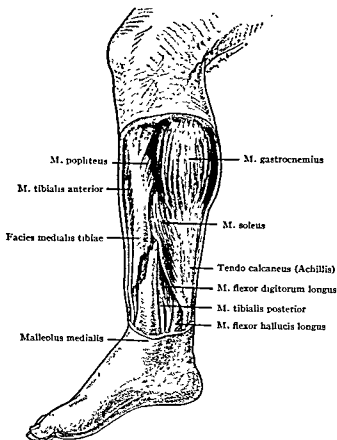


Fig. 1005. OBLIQUE FRACTURE OF THE SHAFT OF THE TIBIA.

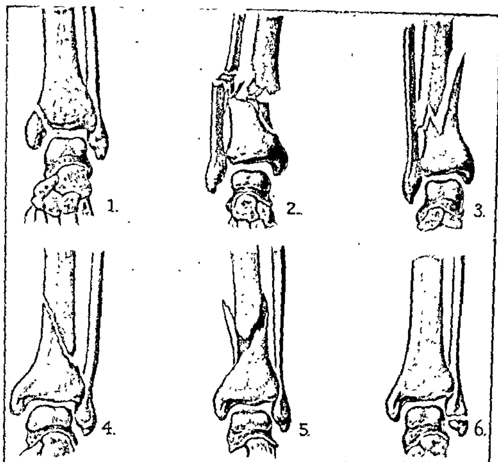


Fig. 1006. VARIETY OF FRACTURES IN THE LOWER THIRD OF THE LEG.

1, Fracture of the medial malleolus; 2, comminuted fracture of the tibia and fibula at the junction of the lower and middle thirds; 3, oblique fracture of the tibia, with outward displacement of the upper fragments; 4, oblique fracture of the tibia without displacement; 5, spiral fracture of the lower third of the tibia; 6, fracture of the lateral malleolus. (Eisendrath, in Keen's Surgery.)

mediately from causing further damage by proper splinting. In this type of fracture, displacement may be great. The weight of the foot causes the leg to bend, and the direct traction exercised by the calf muscles draws the heel backward and angulates the leg forward at the fracture line. If the fracture is oblique, there is sometimes much overriding. The obstacle to reduction of this and other leg fractures with displacement is the contraction of the posterior muscles of the leg. To overcome their tension, the leg is flexed to a right angle. With the leg maintained in this position by countertraction, extension can be made steadily in a downward direction until reduction is effected. The essential principle in treatment is that reduction be obtained without deviation in the normal plane of weight-bearing at the ankle joint. If the plane is altered, the weight of the body no longer falls perpendicularly upon the arch of the foot, and strain occurs, rendering the foot, ankle and knee painful in weight-bearing. If preservation of the normal curves of the tibia (p. 1053) is impossible, it is better that deformity consist in an exaggeration of the normal curves rather than that they be obliterated. If deformity in the anteroposterior plane occurs, angulation with the convexity forward is always preferable in any portion of the tibial shaft.

A short oblique or a spiral oblique fracture, or a fracture with a butterfly segment, is frequently difficult to handle by cast immobilization, even with the cast extending above the knee, holding the knee in flexion. In this case it is frequently wise to carry out an open reduction and use two, three or four transfixion screws across the fracture site as necessary to maintain alignment and position. If the fracture is originally an open fracture and débridement is necessary and can be carried out within a few hours after the injury, transfixing of the oblique fragments should be carried out at that time and the incision closed tightly to avoid the serious complication of infection at the fracture site.

CHAPTER 38

Ankle

The ankle presents for consideration the ankle joint, composed of the tibia and fibula proximally, the talus (astragalus) distally, and the structures surrounding it. The subcutaneous tissue is scant, and the skin is molded over the soft parts so closely that the contour of the bones and the direction taken by the principal tendons can be distinguished readily. Unless the swelling is too great, deviations from normal bony relationships, such as occur from fracture or dislocation, or both, are evident. The malleoli are the most obvious landmarks and serve as important guides in operations about the ankle. They subdivide the soft parts into anterior and posterior divisions.

Structures about the Ankle Joint

STRUCTURES ABOUT THE ANTERIOR REGION OF THE ANKLE. The landmarks of the anterior region of the ankle are of considerable surgical importance (Figs. 1007 to 1010). The lateral malleolus is small and thinly covered. It tapers into a point which lies about 0.5 cm. below and 2 cm. behind the plane of the tip of the medial malleolus. Above its tip, for a distance of 7.5 cm., the shaft of the fibula is subcutaneous and is palpated readily. Anterior to the malleolus and lateral to the tendon of the peroneus tertius is a shallow depression indicating the level of the ankle joint. A similar depression lies between the medial malleolus and the tibialis anterior tendon. At these two points the ankle joint is superficial, and, in joint effusion or in intra-articular overgrowth of granulation tissue, these areas become filled out and form soft projections which may be elevated by the distended capsule. When the foot is in active plantar flexion, the talus (astragalus) glides forward out of its socket and forms a distinct prominence, most apparent in front of the lateral malleolus.

The medial malleolus is large, flat and prominent (Fig. 1007). The resistant surface immediately in front of it corresponds to the medial aspect of the head and neck of the talus. On deep pressure about a fingerbreadth below the malleolus, the sustentaculum tali of the calcaneus is felt. It is obscured somewhat by the tendon of the flexor digitorum longus, which crosses its medial aspect. The flexor hallucis longus tendon grooves the plantar surface of the sustentaculum. When the dorsiflexed foot is inverted actively, the tendon of the tibialis anterior stands out strongly and can be traced downward across the medial part of the ankle joint to a medial insertion into the first metatarsal and the corresponding cuneiform bone. The tendons of the extensor digitorum communis and extensor hallucis longus stand out in bold relief. The dorsalis pedis artery is superficial, and its pulsations can be felt readily. The internal saphenous vein begins in the medial part of the venous arch of the dorsum of the foot and ascends in front of the medial malleolus, where it usually can be recognized.

STRUCTURES ABOUT THE POSTERIOR REGION OF THE ANKLE. The prominent tendo calcaneus is the structure of chief importance in the posterior region of the ankle (Figs. 1009, 1011). That part of the calcaneus intervening on each side between the calcaneal tendon and the corresponding malleolus is grooved considerably, and that on the lateral side is overlaid by the tendons of the peroneus brevis and longus muscles, both of which are bound down tightly by a stout thickening of the deep fascia, the superior retinaculum (external annular ligament). This ligament stretches between the posterior border of the malleolus and the lateral aspect of the calcaneus, converting the groove behind the malleolus into an osteo-aponeurotic canal. The peroneus brevis tendon is the deeper and more anterior of the

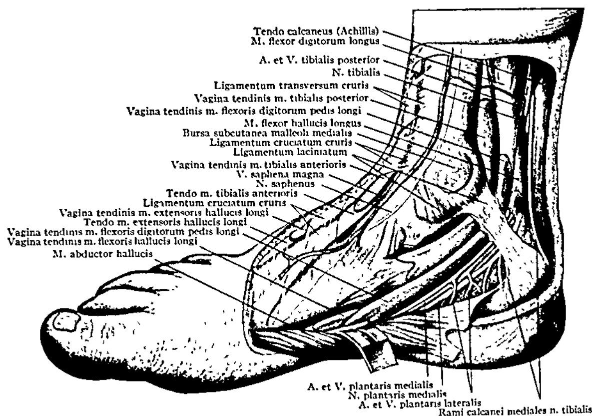


Fig. 1007. SUPERFICIAL STRUCTURES OF THE ANTEROMEDIAL REGION OF THE ANKLE AND FOOT.

two and is in direct contact with the bone. Both tendons can be felt winding around the malleolus, but they diverge a little farther forward. The tendon of the peroneus brevis, which is uppermost at this level, passes anterior to the trochlear process of the calcaneus, and across the calcaneocuboid joint to an insertion into the upper aspect of the base of the prominent tuberosity of the fifth metatarsal bone. The tendon of the peroneus longus passes forward and downward beneath the trochlear process to the lateral margin of the foot, where it hooks around the lateral border of the cuboid. It crosses the sole obliquely forward and medially to the base of the first metatarsal. These tendons (Fig. 1010) become prominent when the foot is everted actively.

The synovial sheaths of the peroneus muscles are sometimes involved by tuberculosis. It is important that the disease be recognized and eradicated at an early stage, lest the infection spread along the sheath of the peroneus longus into the plantar region and infect the tarsal joints. Access to the sheaths is afforded by the lateral J-shaped incision of Kocher (Fig. 1025). To ensure complete removal of the involved tissues, the retinacula must be severed and the synovia dissected away.

The interval between the medial malleolus and the calcaneus is bridged by the laciniate (internal annular) ligament, which contributes to the formation of an osteo-aponeurotic canal to hold the tendons of the tibialis posterior, the flexor digitorum longus and the flexor hallucis longus muscles, and the posterior tibial vessels (Fig. 1007).

The tendon of the tibialis posterior lies immediately against the back of the malleolus and can be traced from this point to the medial margin of the foot and into the tuberosity of the navicular, its principal point of insertion. This tendon is succeeded by those of the flexor digitorum longus and the flexor hallucis longus. Between the last two tendons are the posterior tibial vessels and nerve.

The calcaneus tendon with the small plantaris tendon is brought into prominent relief by flexing the foot. It is narrowest opposite the base of the malleoli, but widens out a little as it approaches its insertion. By splitting the deep fascia, the tendon is found in a space surrounded by a synovial sheath which greatly facilitates its movements. Synovitis of the sheath accounts for one variety of *achillodynia.* Whereas the other tendons lie in close relation to the ankle joint, the calcaneal tendon is

Fascia cruris
Malleolus medialis
M. peronaeus tertius
Malleolus lateralis
Vagina tendinis m. tibialis anterioris
Ligamentum cruciatum cruris
A. dorsalis pedis
Vagina tendinis m. extensoris digitorum pedis longi
A. tarsea lateralis
M. extensor hallucis brevis
Vagina tendinis m. extensoris hallucis longi
Tendo m. peronaei brevis
M. abductor digiti quinti
Os metatarsale I
M. abductor hallucis
A. arcuata
M. extensor digitorum brevis
M. interosseus dorsalis
Bursae intermetatarsophalangeae
Phalanx I
Aponeuroses tendinum extensorum digitorum pedis

Fig. 1008. SUPERFICIAL STRUCTURES ABOUT THE ANTERIOR REGION OF THE ANKLE AND THE DORSAL REGION OF THE FOOT.

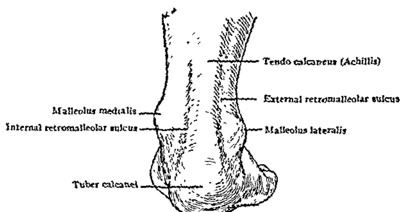


Fig. 1009. LANDMARKS ABOUT THE POSTERIOR REGION OF THE ANKLE AND FOOT.

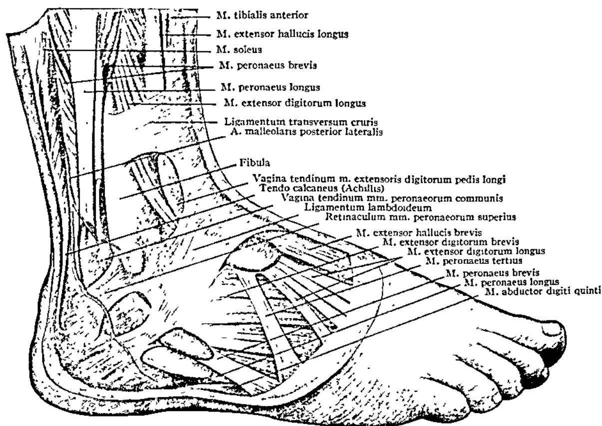


Fig. 1010. SUPERFICIAL STRUCTURES OF THE ANTERO-EXTERNAL REGION OF THE ANKLE AND FOOT.

separated from it by a considerable interval (Fig. 1011). A fairly wide gap filled with fatty areolar tissue also intervenes between the tendon and the posterior tibial vessels, so that there is little risk of damaging these vessels in operating upon the tendon.

Deep Fascia. The strong deep fascia at the ankle is directly continuous with the fascia investing the leg and foot. It forms well defined bands in front of and at each side of the ankle which maintain the ankle tendons in contact with the bones and assist in forming osteo-aponeurotic canals, through which the tendons and their synovial sheaths move with the greatest freedom (Figs. 1007, 1008, 1010).

The anterior thickening has two divisions, an upper and a lower. The upper division, or *transverse ligament*, stretches between the anterior borders of the tibia and fibula immediately above the ankle joint. It covers two compartments, a medial, occupied by the tibialis anterior muscle, and a lateral, occupied by the extensor hallucis longus, extensor digitorum longus and peroneus tertius muscles. The lower division, or *cruciate ligament*, is attached laterally to the prominent anterior tuberosity of the calcaneus and, at first, consists of a single band. As it crosses in front of the joint it divides into two limbs which diverge from each other like the limbs of a Y. The upper limb of the ligament attaches to the medial malleolus, and the lower fuses with the deep fascia along the medial margin of the foot and with the plantar fascia. The cruciate ligament bounds three distinct compartments. The medial of these is occupied by the tendon of the tibialis anterior, the lateral by the tendons of the extensor hallucis longus (Fig. 1008). Each compartment is lined with a synovial sheath. Infection in the tendon sheaths about the ankle extends easily to the ankle joint. Synovial membrane involvement by tuberculosis usually is secondary to tuberculosis in the astragalus.

On the medial side of the ankle joint the *laciniate* (*internal lateral*) *ligament* bridges the hollow between the medial malleolus and the calcaneus, to both of which it is attached. It holds in place the tendons of the tibialis posterior, flexor digitorum longus and flexor hallucis longus. Synovial sheaths enclose these tendons where they lie under the ligament and where they extend forward into the sole of the foot (Fig. 1007).

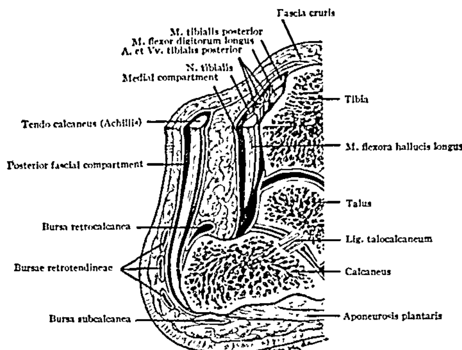


Fig. 1011. COMBINED SAGITTAL AND TRANSVERSE SECTION THROUGH THE RIGHT ANKLE TO SHOW THE SYNOVIAL BURSAE AND THE CELLULAR SPACES ABOUT THE CALCANEAL TENDON.

(Modified from Testut and Jacob.)

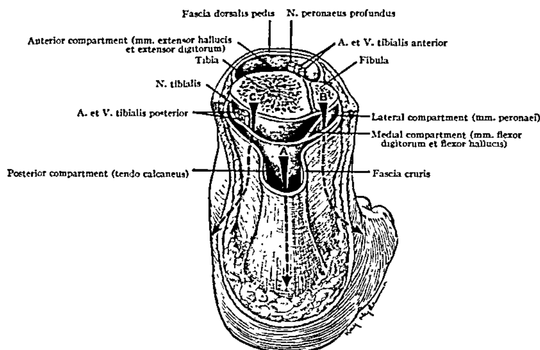


Fig. 1012. DEEP FASCIAL SPACES OF THE POSTERIOR REGION OF THE RIGHT ANKLE.

A, Indicates that the median space terminates below on the upper surface of the calcaneus; *B*, marks the lateral space which passes to the plantar region; *C*, indicates that the medial fascial compartment leads to the plantar region. (Modified from Testut and Jacob.)

On the lateral side of the ankle joint two thickened bands or retinacula (external annular ligaments) bridge the groove between the lateral malleolus and the calcaneus, which holds the tendons of the peroneus longus and brevis (Fig. 1010). The *superior retinaculum* has a single compartment lined by a common synovial sheath. The *inferior retinaculum* holds the tendons to the lateral aspect of the calcaneus above and to the trochlear process (peroneal tubercle) below. The process divides the retinaculum into two compartments, each lined with synovial membrane, which are continuous with the common sheath above. Violent contraction of the peronei may rupture either or both of the retinacula and dislocate the tendons from their position.

VESSELS ABOUT THE ANKLE. The *anterior tibial artery* is continued into the dorsalis pedis beyond the line of the ankle joint (Fig. 1008). Just proximal to the joint line the anterior tibial artery is crossed by the tendon of the extensor hallucis longus. At a lower level it lies between the tendon of this muscle and that of the extensor digitorum longus. About the ankle it gives off the malleolar branches.

The *posterior tibial artery* corresponds to the center of a line connecting the internal malleolus and the most prominent part of the heel (Fig. 1007). Opposite the lower margin of the laciniate ligament the artery terminates in medial and lateral plantar arteries (Fig. 1028). The calcaneal branches of the parent trunk and of its lateral plantar branch nourish the tissues at the medial side of the heel.

The anterior branch of the *peroneal artery* crosses the ankle joint in front of the interosseous ligament between the lower extremities of the tibia and fibula. The anterior and posterior tibial arteries and the peroneal artery form anastomotic networks about the ankle and heel.

INJURY AND REPAIR OF THE CALCANEAL TENDON. Violent muscle effort sometimes ruptures the calcaneal tendon and the plantaris tendon in the constricted portion slightly above their insertions. Occasionally, instead of rupturing, the calcaneal tendon tears off the postero-inferior part of the calcaneus (fracture by avulsion). To approximate the fragments of the tendon, it may be necessary to lengthen the tendon by a series of hemisections along each margin. After tendon suture the knee is flexed and the foot is placed in the equinus position to relax the gastrocnemius and soleus muscles.

The retrocalcaneal bursa often becomes inflamed, tender and painful (achillodynia) from injury to the tendon sheath. Mild forms of this condition, calcaneal bursitis or periostitis, occur from the strain of prolonged walking when the heel of the shoe is much lower than the heel usually worn. The condition is relieved by rest or by taking some of the strain off the tendon by elevating the heel or by placing a felt lift within the shoe.

Bones and Joints

Within the ankle are the lower extremities of the tibia and fibula and that part of the talus (astragalus) with which they articulate to form the ankle joint. It is difficult to differentiate the ankle from the foot, because the talus is related equally to the bones of both. Weight-bearing, proper alignment, and motion at the ankle joint depend not only upon the subtaloid and other tarsal joints, but also upon the integrity of the ankle joint mortise. The securing ligaments extend beyond the proper confines of the joint to the navicular and cuboid bones in front and to the calcaneus below.

ARTICULAR EXTREMITIES. The medial surface of the *lower extremity of the tibia* extends into the strong, blunt, pyramidal medial malleolus (Fig. 1013). The lateral surface presents the fibular notch, a rough depression for the attachment of the inferior interosseous ligament of the distal tibiofibular joint. The posterior margin of the inferior extremity of the tibia is prominent and is sometimes known as the third or "posterior malleolus" of the ankle. This process is often fractured in eversion fracture of the ankle (p. 1079). Only the inferior part of the notch has a cartilaginous covering. The inferior or articular surface is concave, and its cartilage extends mesially to merge with that covering the joint surface of the medial malleolus.

The *lower extremity of the fibula* forms the lateral malleolus, which extends to a lower level than the medial malleolus (Fig. 1013). Above the articular surface for the talus the fibula is rough and convex for attachment to the tibia.

Ossification centers for the distal extremities of the tibia and fibula appear about the second

year, and the epiphyses formed are fused to the shafts between the sixteenth and nineteenth years. The tibia has an epiphysis for the medial malleolus and part of the shaft, but the fibula has one for the lateral malleolus only.

Because the fibula projects below the tibia, the epiphysial lines are located at different levels, in consequence of which the distal extremity of the fibular diaphysis is related to the tibial epiphysis and to the cavity of the distal tibiofibular joint, when that joint is present. The fibular diaphysis sometimes is intracapsular. These considerations are important in ankle joint involvement from osteomyelitis originating in the juxta-epiphysial parts of the diaphyses. Separation of the epiphyses may result from violent displacements of the foot medially or laterally, but the accident is rare because of the difference in level between the two epiphysial lines. The more usual occurrence is lateral displacement of the tibial epiphysis with transverse fracture of the fibula at a higher level.

The *talus* (*astragalus*) consists of a body which articulates with the tibia and fibula by its upper or trochlear surface, a forward-projecting neck, and a head which articulates with the navicular (scaphoid). The inferior surface of the body of the talus rests upon the calcaneus, which is able to rotate slightly beneath it. Because of the inversion and eversion which take place between the talus, navicular and calcaneus, the ankle joint is spared much wear and tear. However, the movements are not sufficient to protect the ankle joint from severe and sudden strains. The superior surface of the talus, which is arched evenly anteroposteriorly, rocks in the tibiofibular notch and is broader anteriorly than posteriorly. Should ankylosis in the ankle joint occur from disease, injury or arthrodesis, the tarsal joints replace ankle joint function to a slight degree.

The talus is covered entirely with the cartilage of its numerous articular surfaces except for a small surface of periosteum through which it receives its blood supply. Like the other bones of the tarsus, it usually develops from one center of ossification. The bone is often a site for tuberculosis.

DISTAL TIBIOFIBULAR JOINT. The distal tibiofibular joint usually is a simple apposition of the convex fibular surface and the concave tibial surface without the interposition of an articular cartilage (Fig. 1013). This type of

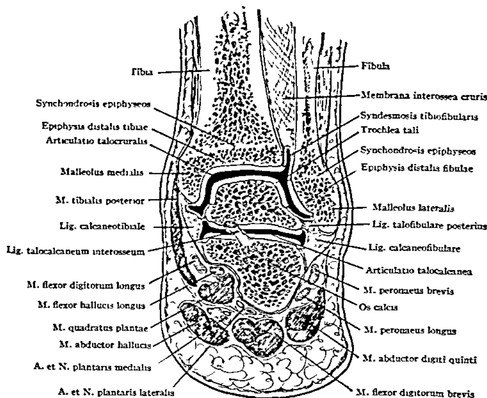


Fig 1013. FRONTAL SECTION THROUGH THE ANKLE JOINT.

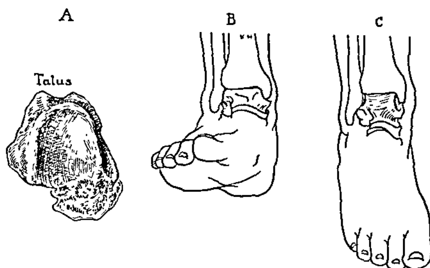


Fig. 1014. DIAGRAMS ILLUSTRATING THE RELATIONS BETWEEN THE SUPERIOR AND LATERAL ARTICULAR SURFACES OF THE TALUS AND THE TIBIOFIBULAR MORTISE.

A, View of the superior surface of the talus, showing that the anterior part of the articular surface is wider than the posterior. *B*, Illustrates the tightness of the mortise when the foot is in dorsiflexion. *C*, Shows that the mortise is loose when the foot is in plantar flexion. (After Homans.)

joint, a syndesmosis, is very resistant and permits no movement save elasticity. This feature is important in maintaining the stability of the ankle mortise in trauma.

The tibia and fibula are connected by the strong *interosseous ligament*, which is the inferior prolongation of the interosseous membrane, and by the *inferior transverse ligament*, which extends from the posterior part of the medial surface of the lateral malleolus to the posterior margin of the distal extremity of the tibia. The inferior transverse ligament is a stout band which aids materially in increasing the extent of the tibiofibular arch. Anterior and posterior tibiofibular ligaments reinforce the joint. Occasionally there is a tibiofibular joint cavity; its synovial membrane is an upward prolongation of that lining the ankle joint.

ANKLE (TALOCRURAL) JOINT. At the ankle joint the talus articulates by its superior or trochlear surface with the tibia and on each side with the malleoli, as in a mortise. The roof or bearing surface of the joint is formed entirely of the tibia (Fig. 1014). The necessary stability of the joint is obtained by the downward projection of the malleoli, which form the clasping surfaces of the mortise on each side of the talus and permit only a slight amount of lateral movement. The fibular malleolus is considerably the deeper, and the articular surface of the astragalus applied to it is correspondingly larger than that applied to the medial malleolus. This conformation doubtless is a factor in the mechanism of fracture of the lower end of the fibula resulting from forced movements of the foot.

The superior surface of the talus is wider in front than behind; hence lateral movements at the ankle mortise occur more freely when the foot is plantar-flexed than when it is dorsiflexed. When the foot is flexed to a right angle, the broad anterior part of the trochlear surface of the talus fits tightly into the tibiofibular mortise; when the foot is extended, the narrow posterior part of the upper surface of the talus lies loosely in the mortise and admits a small amount of play between the malleoli. Motion at the ankle is only in an anteroposterior direction. Flexion and extension take place about a slightly oblique anteroposterior axis through the body of the talus, so that the foot points slightly mesially in flexion and somewhat laterally in dorsiflexion.

LIGAMENTS AND SYNOVIA OF THE ANKLE. The *capsular ligament* is relatively weak, particularly anteriorly and posteriorly. It is attached proximally to the margins of the articular surfaces of the tibial and fibular epiphyses and distally to the margin of the superior articular surface of the talus, except at the anterior aspect of the joint, where it extends forward to the neck of the bone. The *synovial membrane* is lax in front and behind where it is covered by the anterior and posterior ligaments and where the capsule is thin and loose.

It is directly continuous with the synovial membrane of the distal tibiofibular joint. A joint effusion bulges the synovial membrane and the weak capsule anteriorly and posteriorly. *Aspiration* of the ankle joint is performed between the tip of either malleolus and the corresponding articular surface of the talus.

The *anterior ligament* of the ankle is a thin membrane attached to the anterior aspect of the malleoli and the lower extremity of the tibia, and below to the rough upper surface of the neck of the talus. The *posterior ligament* is the weakest of the ankle ligaments, and is represented by a few ligamentous bands connecting the inferior surface of the tibia and the posterior tibiofibular ligament to the posterior aspect of the talus below. The tendon of the flexor hallucis longus is a strong posterior support of the joint.

The ligaments which reinforce the medial and lateral aspects of the joint are strong and pass fanlike from the malleoli to the tarsal bones (Figs. 1015 to 1017). The *deltoid (internal lateral) ligament* strengthens the mesial side of the joint to a great degree (Fig. 1016). It is an extensive triangular sheet of ligamentous fibers, inseparable from the joint capsule. The apical extremity of the ligament attaches to the medial malleolus. The lower or basal extremity anteroposteriorly presents an unbroken line of attachment to the navicular, talus, sustentaculum tali and to the plantar calcaneonavicular ("spring") ligament. It is reinforced by the tendons of the tibialis posterior and flexor digitorum longus. Violent strains upon the deltoid ligament, when the foot is overeverted, usually pull off the medial malleolus instead of rupturing the ligament.

The *lateral ligament* is weaker and less complete; it is divided into anterior, middle and posterior fasciculi (Fig. 1017). The anterior talofibular ligament extends from the anterior border of the lateral malleolus to the lateral surface of the neck of the talus. The calcaneofibular ligament is a band extending obliquely downward and backward from the malleolus to the lateral surface of the calcaneus. It is overlaid by the peroneal tendons. The posterior talofibular ligament binds the fibula to the talus rigidly, and rarely is torn. In the extremes of dorsiflexion and plantar flexion the impingement of the edges of the tibia prevents further movement. The deltoid and lateral ligaments restrict motion.

LATERAL MOVEMENTS AT THE FOOT AND ANKLE. *Inversion*, or tibial flexion, turns the sole of the foot medially, and *eversion*, or fibular flexion, turns it laterally (Fig. 1018). In both these lateral movements the foot rotates around an anteroposterior axis in a limited range of motion in the subastragaloid joint. Movements of this sort are checked by the lateral ligaments of the ankle. *Adduction* and *abduction* refer to those movements which

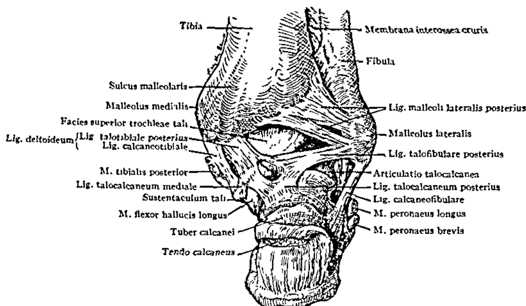


Fig. 1015. POSTERIOR VIEW OF THE LIGAMENTS AND TENDONS ABOUT THE RIGHT ANKLE JOINT.

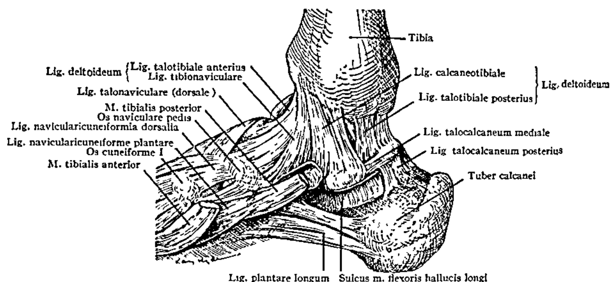


Fig. 1016. MEDIAL LIGAMENTS OF THE RIGHT ANKLE JOINT.

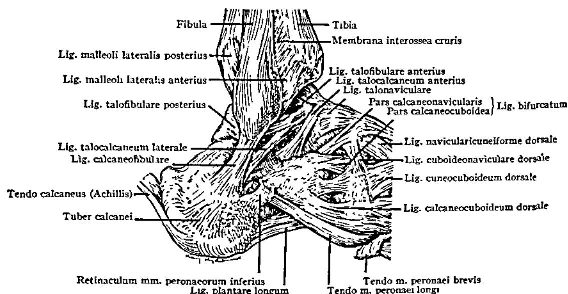


Fig. 1017. LIGAMENTS OF THE LATERAL REGION OF THE ANKLE AND FOOT.

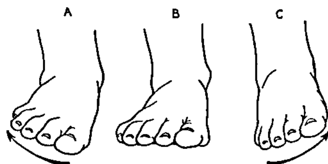


Fig. 1018. DIAGRAM OF THE MOVEMENTS OF EVERSION AND INVERSION OF THE FOOT.
A, Eversion; *B*, normal position; *C*, inversion.

turn the front of the foot medially and laterally, respectively. They are confined mainly to the joints between the anterior and posterior segments of the tarsus—the midtarsal joint (p. 1092).

The combined movement of inversion and adduction is *supination;* that of eversion and abduction is *pronation.*

Surgical Considerations

Injuries about the ankle commonly follow twists and falls in which the body weight is transmitted in a direction out of line with the usual axis. Their nature often depends upon the position into which the foot is forced by the violence, whether it is one of overinversion and adduction or overeversion and abduction. Lesions are prevented to a large extent by the strength of the lateral ligaments of the joint, the adaptability of the talus in its mortise, and the support given by the powerful tendons surrounding the joint. In the presence of deformity the direction in which the foot is displaced is the clue to the kind of fracture and governs the manipulation by which reduction is secured.

SPRAINS. A sprained ankle usually is an inversion injury in which the foot is rocked toward the median line and some part of a ligament is torn (Fig. 1019). A violent motion of this sort puts a strain on the lateral ligament until its talofibular, and sometimes its calcaneofibular, components are ruptured. Avulsion of the lip of the lateral malleolus may be associated with the sprain and is known as a *sprain fracture.* Should the lateral ligament remain intact, the strain is transferred to the fibula, and an inversion fracture occurs in which the lateral malleolus is broken off at its base. Injuries sustained by violent eversion of the foot rarely take the form of sprains, since the medial or deltoid ligament is very strong. They usually result in some form of Pott's fracture.

In sprain, point tenderness is elicited on palpation over the attachments of the torn ligament, but none is elicited over the subcutaneous surface of the fibula. Swelling and ecchymosis are often greater than when a fracture is present.

POTT'S EVERSION FRACTURE. Pott's fracture is a combination of injuries to the tibia and fibula caused by forcible eversion or abduction of the foot, or a combination of these closely related movements (Figs. 1020, 1021). It may be caused by a stumble or fall in which the foot fails to receive the weight of the body squarely.

Pott's fracture varies in its clinical manifestations according to whether it is caused by eversion or abduction of the foot. In the

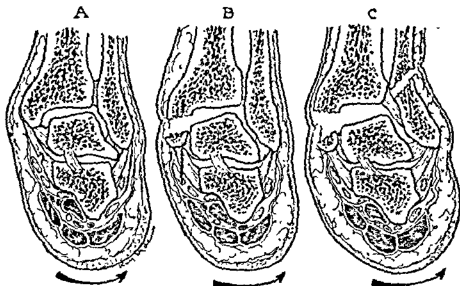


Fig. 1019. SCHEMATIC FRONTAL SECTIONS THROUGH THE RIGHT ANKLE TO SHOW THE MECHANISM OF SPRAIN AND FRACTURES CAUSED BY ABDUCTION AND EVERSION OF THE FOOT.

A, Abduction sprain in which the deltoid (medial) ligament is torn. *B,* Abduction fracture of the tip of the medial malleolus, the ligaments remaining intact. *C,* Typical abduction and eversion fracture with fracture of the shaft of the fibula. (Modified from Testut and Jacob.)

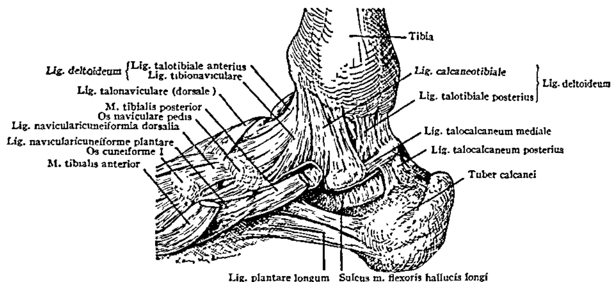


Fig. 1016. MEDIAL LIGAMENTS OF THE RIGHT ANKLE JOINT.

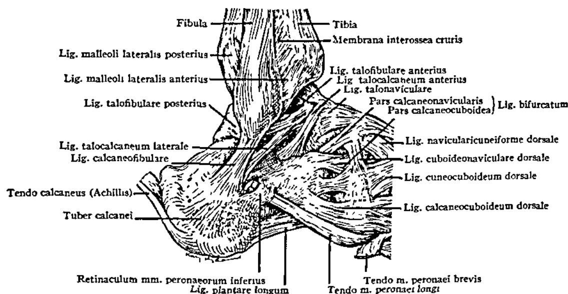


Fig. 1017. LIGAMENTS OF THE LATERAL REGION OF THE ANKLE AND FOOT.

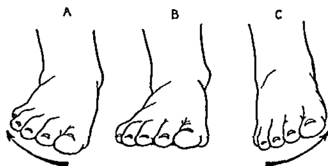


Fig. 1018. DIAGRAM OF THE MOVEMENTS OF EVERSION AND INVERSION OF THE FOOT.
A, Eversion; *B*, normal position; *C*, inversion.

characteristic deformity. In the erect attitude the medial border of the foot is directed toward the ground, and its lateral edge is raised. The lower end of the tibia projects prominently on the medial side, and there is an angular depression between the foot and leg at the site of the fibular fracture.

Since all fractures of this group enter the joint, only an accurate *reduction* can restore the planes of the articulating surfaces to normal weight-bearing alignment. Accumulation of blood and exudate and fixation of the part by muscle spasm oppose reposition of the fragments unless reduction is made at the earliest possible moment. In this type of fracture the foot usually is everted, abducted, and not infrequently is displaced backward, and the tibia and fibula tend to separate. In the procedure the knee is flexed to relax the pull of the gastrocnemius muscle; traction is made on the foot in plantar flexion, and the foot as a whole is displaced medially if lateral dislocation is present, and anteriorly if there is posterior dislocation. The foot is then adducted, inverted and dorsiflexed.

In standing or walking after union of Pott's fracture in malposition, the weight of the trunk is no longer transmitted through the tibia and the center of the ankle joint to the sole of the foot, but is supported by the lateral part of the tibiofibular mortise and is transferred to the medial border of the foot. The greater the use of the limb under these conditions, the greater becomes the deformity and disability.

Reversed Pott's or Inversion Fracture. A reversed Pott's or inversion fracture results from violently turning the foot medially. Adduction may be a feature, adding a medial rotation to the inversion of the foot. The force causing the fracture is that which causes the common sprain or sprain fracture. Traction on the lateral ligament may rupture it partially or completely without avulsion of the tip of the lateral malleolus, or a tearing off of its base below the attachment of the interosseous ligament. The force, continuing to act without opposition, presses the talus against the medial malleolus, and knocks off its tip or splits the malleolus from the tibia in a longitudinal direction (Fig. 1023). In addition, there may be fracture of the anterior articular edge of the tibia. In these injuries there is none of the separation of the tibia and fibula which may occur in eversion fractures, and there is little tendency to posterior displacement of the foot. *Reduction* is effected by abduction, eversion and full dorsiflexion.

Dislocations. Lateral and posterior displacements, with the talus maintaining its normal relations with the associated tarsal bones, have been described in connection with Pott's fracture. The extreme rarity of medial dislocation probably is accounted for by the fact that a great amount of force is required

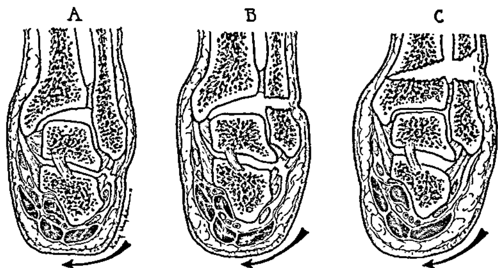


Fig. 1023. SCHEMATIC SAGITTAL SECTIONS THROUGH THE RIGHT ANKLE TO SHOW THE MECHANISM OF SPRAIN AND FRACTURE (REVERSED POTT'S) CAUSED BY ADDUCTION AND INVERSION OF THE FOOT.

A, Sprain from a tear of the lateral ligament *B*, Lesion in which the lateral ligament is lacerated and the lateral malleolus is wrenched off. *C*, Transverse supramalleolar fracture. (Modified from Testut and Jacob.)

abduction form the foot is subjected to an outward rotary strain. The anterior part of the talus, maintaining its normal relations with the tarsal bones, impinges against the lateral malleolus, causing an oblique separation of the malleolus from the shaft above. The strain then falls on the medial or deltoid ligament, which tears off the medial malleolus or is ruptured. A continuation of the rotating force tears away a part of the posterior margin of the tibia along with the lower fragment of the fibula. In either instance the talus slips backward, producing a posterior dislocation of the foot.

When *eversion* is the prevailing mechanism, great strain is thrown at once upon the deltoid ligament. This ligament rarely gives way, but the internal malleolus frequently snaps across.

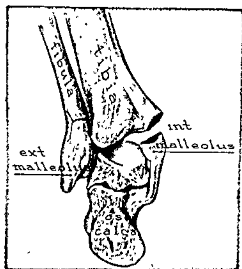


Fig. 1020. POTT'S FRACTURE OF THE ANKLE.

(From Babcock: Textbook of Surgery.)



Fig. 1021. POTT'S FRACTURE OF THE ANKLE WITH ABDUCTION AND EVERSION OF THE FOOT.

(From Babcock: Textbook of Surgery.)

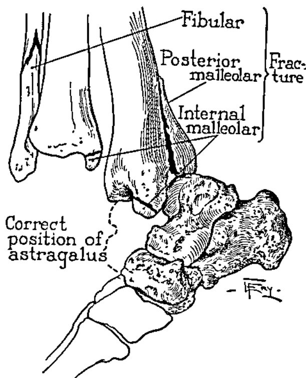


Fig. 1022. TRIMALLEOLAR FRACTURE OF THE ANKLE WITH POSTERIOR DISPLACEMENT OF THE FOOT.

(From Henderson: Surg., Gynec. & Obst., 60: 535–9, 1935.)

Abduction without the check of the internal malleolus presses the talus (astragalus) against the tip of the lateral malleolus. The inferior tibiofibular ligament remains intact, and the lower part of the fibular shaft is bent medially toward the tibia and is broken across, allowing the foot to be deflected laterally. In an eversion fracture in which the leg is in forward motion and the foot maintains contact with the ground, the posterior edge of the tibia is sometimes broken off by the astragalus. This edge of the tibia is known as the third or posterior malleolus. Pott's fracture with fracture of the posterior malleolus is known as a "trimalleolar" fracture (Henderson). In this fracture there is a partial posterior dislocation of the foot (Fig. 1022).

Should the tibiofibular ligaments rupture or tear off a fragment of tibia, the tibia and fibula separate, and the fibula is broken by bending in its lower third. In this case the talus is carried to the lateral side of the tibial articular surface and upward to a varying extent. The foot also is drawn upward on the lateral side of the leg. The lower extremity of the fibula retains its connection with the talus.

Pott's fracture is recognized easily by its

for its production. Simple dislocation unassociated with fracture sometimes occurs.

Posterior and anterior dislocations of the foot at the ankle without fracture are unusual, contrary to what might be expected from the configuration of the joint (Fig. 1024). *Posterior dislocation* is much more frequent than anterior dislocation, and results from sudden arrest or fixation of the foot while moving forward. In the simple dislocation there is extensive tearing of ligaments until the talus is enabled to slide out behind the posterior edge of the tibia. The characteristic deformity is prominence of the heel, apparent shortening of the foot, and broadening of the ankle. From the anatomic nature of the joint, an *anterior dislocation* of the foot at the ankle could occur readily. However, as violence to the foot usually occurs with the patient moving forward, this type of dislocation is rare. For reduction, the knee is flexed to relax the calf muscles. Extension of the foot with traction and manipulation reduces the dislocation.

Upward dislocation with the talus forced upward between the malleoli may result from falls upon the feet. The lower end of the tibia is split, but the fibula usually is not broken. Unless the foot is drawn downward by skate or pin traction to narrow the mortise, the lateral malleolus impinges against the os calcis, and the ankle is greatly broadened.

APPROACH FOR ARTHRODESIS OF THE ANKLE JOINT. Arthrodesis of the ankle by removal of joint cartilage reduces the size of the talus and at the same time increases the size of the mortise into which it is to be received. Ade-

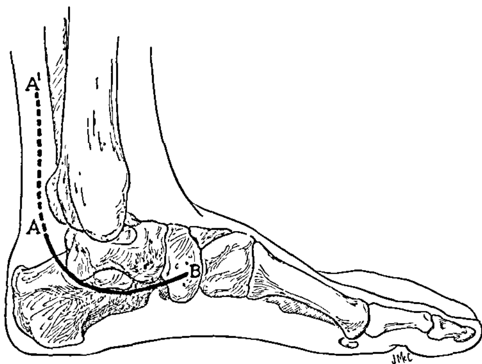


Fig. 1026. MEDIAL APPROACHES TO THE ANKLE JOINT.

The *short curved incision, A–B,* begins ½ inch posterior to the lower end of the medial malleolus and extends downward and forward to the tip of the navicular bone. The tendons of the flexor digitorum longus and tibialis posterior are removed from their sheaths and retracted anteriorly. The *long curved incision, A′–B,* is essentially a 2-inch extension upward of the short incision along a line midway between the posterior surface of the tibia and the tendo calcaneus.

Using the more posterior approach, the *short curved incision, A–B,* begins ½ inch posterior to the lateral malleolus and is carried forward ½ inch below the tip of the malleolus to the front of the navicular bone. For exposure of the joint, the peroneus longus and brevis tendons are removed from their sheaths and retracted posteriorly. For greater exposure, the *long curved incision, A′–B* (Kocher), is merely a 2-inch extension upward of the short curved incision along a line midway between the tendo achillis and the posterior border of the fibula.

Preference is often shown for the more anterior approach. The *short curved incision, C–D,* begins ½ inch above the tip of the malleolus in front of its most prominent portion and then curves forward to the midportion of the cuboid. For further exposure, the *long curved incision, C′–D,* is a 2-inch extension upward along the anterior border of the fibula.

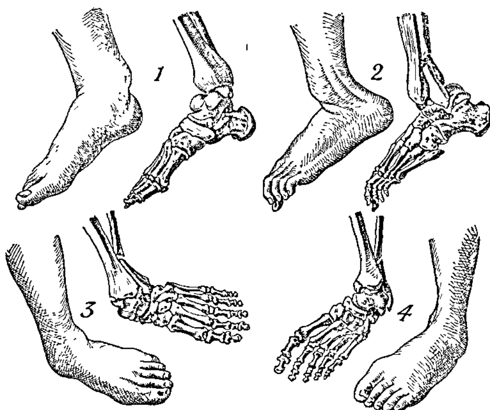


Fig. 1024. VARIOUS FORMS OF DISLOCATIONS ABOUT THE ANKLE.

1, Forward dislocation of the foot; 2, backward dislocation of the foot, associated with fracture of the fibula; 3, lateral dislocation of the foot, associated with fracture of the tibia and fibula; 4, medial dislocation of the foot, associated with fracture of the tibia and fibula. (Hoffa.)

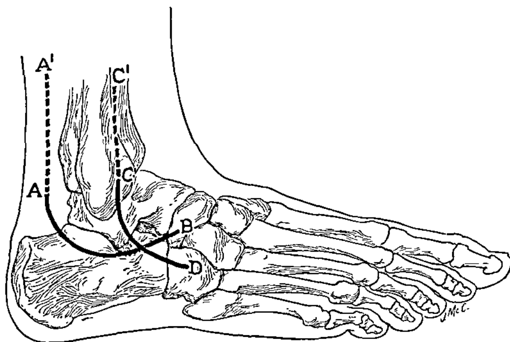


Fig. 1025. LATERAL APPROACHES TO THE ANKLE JOINT.

These incisions are varied in minor details by different surgeons, but essentially have been developed for exposure of the subtalar and subastragalar joints for arthrodeses.

the tibia is removed. The fragments of the fibula are replaced and sutured, and the limb is immobilized in plaster.

In *excision of the talus* the posterior part of the extensor digitorum brevis muscle is elevated, and the talonavicular joint is opened. The head of the talus is drawn upward, so that when the talocalcaneal interosseous ligament is divided, it is held only by the attachment of the deltoid ligament to its mesial aspect. After excision of the talus the sustentaculum tali is removed, and the calcaneus is trimmed to allow it to fit the new position in the tibiofibular mortise. The lateral malleolus projects downward too far and requires shortening. The peroneal tendons are approximated and sutured, and the retinacula are stitched into place over them.

Amputation through the Ankle Joint. Syme's amputation (Fig. 1027) is the only amputation recommended for use at the ankle joint, and is indicated when transection through the foot cannot be performed at a satisfactory level for good function. It is more difficult to obtain a good result with a Syme amputation than with any other amputation of the leg. Unimpaired circulation to the tissues at the ankle is essential. The stump needs to be practically perfect to obtain full end-weight-bearing without pain. The scar must be inconspicuous and the soft parts fit snugly over the bone end. Syme's amputation is less suitable for women because of the somewhat bulbous appearance of the stump, but for men it is able to stand up under hard physical work with a relatively small prosthesis.

The Pirogoff amputation (Fig. 1042) may be regarded as a modification of Syme's. It differs from it in the fact that part of the calcaneus is retained in the heel flap and subsequently is brought into contact with the divided lower extremity of the tibia and fibula. In this operation the calcaneus is sawed through in the line of the incision in the sole. A larger piece of bone is cut from the tibia than is taken from it in Syme's amputation.

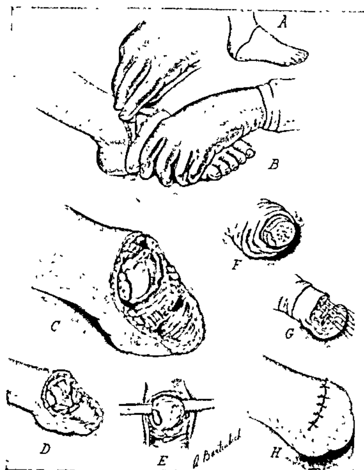


Fig 1027. SYME'S AMPUTATION AT THE ANKLE.

A, Skin incision. *B*, Separating astragalus from malleoli. *C*, Heel flap is cautiously cut away from the calcaneus close to the bone without injuring the posterior tibial vessels on the medial side and the terminal branches of the peroneal on the lateral side. *D*, Posterior tendons grouped together and sutured to the tendon of Achilles. *E*, Articular surface of tibia and fibula removed with a saw. *F*, The periosteum excised from the ends of the bone for about 0.5 cm. *G*, Sutures uniting anterior tendons to the heel pad. *H*, Heel flap closed. A snug dressing is applied to prevent the accumulation of blood and serum. (From Orr: Operations of General Surgery.)

quate exposure for extensive resection may be obtained through the *lateral J-shaped incision* (of Kocher) (Fig. 1025). This incision begins behind the fibula and extends downward below the lateral malleolus to the trochlear process (peroneal tubercle) of the calcaneus. It then curves forward and ends behind the insertion of the peroneus tertius muscle into the tuberosity of the fifth metatarsal. The curved flap thus outlined, consisting of the skin, deep fascia, and periosteum of the lateral malleolus, is dissected forward from the peronei and lateral malleolus.

In the *lateral transfibular approach* to the ankle joint for arthrodesis, the incision is similar to the lateral J-shaped incision of Kocher. After division of the skin and subcutaneous tissue the fibula and the peroneal tendons are exposed. The periosteum is incised longitudinally upward for a distance of 6 cm. from the tip of the lateral malleolus. In the upper third of the periosteal incision, subperiosteal dissection is carried completely around the shaft of the fibula. Osteotomy of the fibula, obliquely downward and medially, is then performed. After levering the distal fragment of the shaft of the fibula laterally, the terminal portion of the interosseous membrane and the distal tibiofibular joint are divided by sharp dissection. Continued leverage on the malleolar fragment exposes the ankle joint. The foot is now displaced medially; the taut peroneal tendons may require division. The articular surfaces of the tibia and fibula, together with the trochlear surface of the talus, are denuded of their cartilage. In order to obtain bony contact for a snug tibiofibular mortise, the lateral surface of the distal end of

anterior to the middle of the interval between this tuberosity and the tip of the lateral malleolus defines the joint between the calcaneus and the *cuboid midtarsal joint* (of Chopart). The *trochlear process* (peroneal tubercle) can be felt indistinctly as a small bony prominence, 2.5 cm. below and a little in front of the lateral malleolus.

LANDMARKS ON THE DORSUM OF THE FOOT. The skin on the dorsum of the foot is thin, but is much less sensitive than that on the plantar surface. The subcutaneous tissue is remarkably loose in texture, so that the edema of cardiorenal disease or of inflammatory lesions of the foot usually is pronounced. The veins are arranged in an arch, the outline of which is often apparent in the erect posture. The large and small saphenous veins arise from the marginal veins of this arch.

The tendons of the front of the ankle may be traced readily to their insertions (Fig. 1008). That for the tibialis anterior has been described. The tendon of the extensor hallucis longus passes forward to the dorsal aspect of the great toe, and the tendons of the extensor digitorum longus are directed to the four outer toes. On the posterolateral aspect of the dorsum of the foot, the soft inelastic mass of the fleshy belly of the extensor digitorum brevis muscle can be felt. The tendon of the peroneus brevis muscle passes forward under the lateral malleolus to an insertion into the projecting tuberosity of the fifth metatarsal.

The dorsalis pedis artery, a continuation of the anterior tibial artery into the foot, runs a course indicated on the surface by a line beginning midway between the two malleoli and ending at the posterior extremity of the first interosseous space. On the lateral side of the vessel is the anterior tibial nerve.

SUPERFICIAL STRUCTURES OF THE SOLE OF THE FOOT. The plantar surface of the foot is triangular in outline and is hollowed out considerably along its mesial border (Fig. 1028). The parts supporting the superincumbent weight are the heel, the ball of the great toe, and the lateral margin of the sole along its entire extent.

The *skin* over these supporting areas is thick and often horny. The rest of the plantar skin is thin, and highly sensitive, and, like that of the palm of the hand, contains numerous sweat glands. The *subcutaneous tissue*, similar to that over the scalp and the palm of the hand, is dense because of the many fibrous septa traversing it. This tough and elastic tissue is reinforced by the strong central portion of the plantar aponeurosis and is thickest over the weight-bearing areas.

PLANTAR APONEUROSIS. The plantar aponeurosis (deep fascia) of the sole of the foot consists of a strong central portion and two weaker lateral divisions (Fig. 1030). It covers and protects the soft parts which play over the plantar surface of the bones and joints and affords an origin to the intrinsic muscles of the sole. The *central portion* is attached behind to the plantar surface of the calcaneal tuberosity, and divides anteriorly into slips connected to the fibrous flexor sheaths of the five toes and to the sides of the metatarsophalangeal joints. This portion is a strong support of the longitudinal arch and is shortened considerably in the deformity known as *pes cavus* and in certain other varieties of talipes. The *medial division*, which covers the abductor hallucis, is weak. It extends from the calcaneal tubercle to the base of the proximal phalanx of the great toe. The *lateral division* is a fairly strong band extending between the calcaneus and the tuberosity of the fifth metatarsal. Because of the density of the central parts of the fascia, swelling in inflammatory conditions of the sole early becomes apparent on the dorsum of the foot.

MUSCLES OF THE FOOT AND THEIR ACTIONS. The foot is controlled by the small short muscles intrinsic to the foot and by long extrinsic muscles which arise in the leg (Fig. 1028). The *small muscles* of the dorsum and sole of the foot are less important than the corresponding muscles in the hand, since the foot is a mechanism for the stable support of the body weight, and movements of the individual toes are of secondary consequence. Most of the small muscles of the sole run longitudinally and strengthen the long arch, while a few run across the foot to support the transverse arch.

The *long muscles* bear most of the weight of the body in locomotion and direct the movement of the foot. They subserve three main functions: supporting the arch of the foot; dorsiflexing and plantar-flexing the foot; and abducting, adducting, everting and inverting the foot. The action of the individual muscles is not simple, since they act on the ankle, the midtarsal and the talocalcaneonavicular (sub-

CHAPTER 39

Foot

The features of the foot adapting it to sustain the great weight thrown upon it in standing and locomotion are a comparatively large size, a position at a right angle to the leg, a distinctive architectural plan of construction, and a broad base of support. The foot has also a remarkable springiness because of the arrangement of the constituent bones and the ingenious interlocking of tendons, ligaments and muscles maintaining the arches.

The movements of the foot are sometimes rapid. Treading on an uneven or unstable surface requires almost instantaneous adjustment in balance lest sprain or even fracture result. In running, the position of its component elements must be accommodated rapidly; in jumping, the elements incur a special strain.

Whereas the hand is essentially an organ of touch and prehension with a remarkable freedom of movement, the foot is an organ of locomotion endowed with strength and solidity; its movements are neither intricate nor numerous. Strength in the foot is enhanced by the fact that its constituent bones are short, solid, and well integrated into a double arch, joined by strong ligaments and supported by powerful tendons. Knowledge of this structure enables one to understand the diseases, injuries and deformities to which the foot is subject, and the means available for their prevention and cure.

Soft Parts of the Foot

In general outline, the foot is triangular—narrowest at the heel and widest at the toes. The soft parts on the medial, lateral and dorsal surfaces are so superficial as to warrant description under the heading of regional landmarks.

LANDMARKS ON THE MEDIAL ASPECT OF THE FOOT. The medial aspect of the foot is arched anteroposteriorly, and rests upon the ground only at its anterior and posterior extremities—the heel, and the ball of the great toe. The skin over the medial aspect of the foot is thin and delicate and is often marked by numerous small vessels, which give it a wavy appearance. The *sustentaculum tali* can be located by feeling 2.5 cm. below the medial malleolus (Fig. 1031). The distinct prominence of the *tuberosity of the navicular* is encountered by pressing about 2.5 cm. in front of, and slightly below the level of, the medial malleolus. This tuberosity is a useful guide in many operations on the foot and is the principal point of insertion for the tendon of the tibialis posterior. The depression below and behind the tuberosity is an absolute guide to the *talonavicular joint.* This angular interval separates the anterior from the posterior segment of the tarsus and is the level at which Chopart's disarticulation (p. 1092) is performed. Nearer the malleolus, another bony prominence, the *head and neck of the astragalus,* is palpable, particularly when the foot is extended and everted.

The first metatarsal lies distal to the *first cuneiform,* which is palpated anterior to the navicular. The *tendon of the tibialis anterior* is recognized readily when the foot is inverted actively, and can be followed to its insertion into the contiguous plantar areas of the first cuneiform and the base of the first metatarsal. The head of the first metatarsal is prominent if the great toe deviates from the midline an abnormal degree (hallux valgus) (p. 1102).

LANDMARKS ON THE LATERAL SURFACE OF THE FOOT. The lateral margin of the foot is thin in contrast with the medial margin, and rests in contact with the ground over its entire extent. Near the middle of the lateral border the prominent *tuberosity of the base of the fifth metatarsal* marks the *tarsometatarsal joint* (Fig. 1031). A point on this margin of the foot just

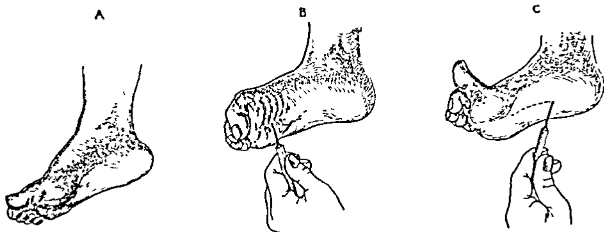


Fig. 1029. PLANTAR REFLEX (OF BABINSKI).

A, The position of the toes before irritation of the plantar surface. *B*, The normal response to irritation is plantar flexion of the toes, particularly of the great toe. *C*, Pathologic response: irritation of the plantar surface causes extension of the toes.

Fasciculi transversi
Exit of pus in direction of webs of toes
M. flexor hallucis brevis
M. abductor digiti quinti
Exit through gaps in aponeurosis—forming hour-glass abscesses
Aponeurosis plantaris
Exit of pus between the flexor brevis and the abductor digiti quinti
M. flexor digitorum brevis
Exit of pus between the abductor hallucis and the flexor brevis
M. abductor hallucis
Pus follows the flexor tendons up behind the medial malleolus
Tuber calcanei

Fig. 1030. PLANTAR ABSCESS.

Diagram shows the points of exit of pus beneath the plantar aponeurosis.



Fig. 1028. DEEP MUSCLES, VESSELS AND NERVES OF THE PLANTAR REGION OF THE FOOT.
The flexor digitorum brevis has been removed to show the deeper structures.

astragaloid) joints. If the ankle joint is stationary, the muscles abduct and evert, and adduct and invert, and, if the subastragaloid joint is fixed, they dorsiflex, plantar-flex, abduct and adduct the foot. When both joints are free, the long muscles act in combination with the small muscles.

The *muscles supporting the tarsal arch* do not belong to any single group. They include the tibialis anterior and posterior, the flexor digitorum longus, flexor hallucis longus, peroneus longus and all the intrinsic muscles of the foot. The tibialis anterior muscle inserts almost into the summit of the arch and supports it by drawing it upward. The flexor hallucis longus and flexor digitorum longus muscles run lengthwise beneath the arch and support it from below. The tibialis posterior and peroneus longus muscles, one from the medial and one from the lateral side, cross in the sole of the foot to opposite sides. They form a cruciate sling immediately under the arch, upon which the arch rests when these muscles contract. Under the strain of locomotion the arch is dependent upon these muscles for support. If they cannot meet the demand made upon them, the strain falls upon the ligaments. The ligaments are static, not dynamic structures like muscles; they quickly weaken, allowing the arch to flatten.

Each of the tarsal bones entering into the tarsal arch slightly underlaps its proximal neighbor. The effect of all the supporting muscles, except the tibialis anterior, is to shorten the foot by their bowstring action beneath the arch, thus crowding together and locking the tarsal articulations against the downward thrust of the body weight, con-

losed, walking and balancing become difficult, and great care is required in locomotion to avoid strain and injury. The bone groups of the foot are the tarsus, metatarsus and phalanges; the first two are the more essential. The toes are used more in balancing, running and climbing than in walking; although they add to the efficiency of the intricate movements of the foot, their loss does not produce serious impairment, for the firmer, more deliberate movements of walking remain almost normal.

The bones of the foot are divided longitudinally into two groups, a medial and a lateral (Figs. 1031 to 1033). Most of the weight of the body is borne through the *medial group*, which is in relation with the tibia. The bones of this group are the talus (astragalus), navicular (scaphoid), three cuneiforms, three medial metatarsals and three medial phalanges. The talus and the navicular are the most likely to be injured. The *lateral group* is in relation with the fibula and is composed of the calcaneus, the cuboid, and the outer two metatarsals with their corresponding phalanges. The lateral group of bones balances the superimposed body weight. Of this group, the calcaneus is most liable to injury.

Bones of the Tarsus and Metatarsus. The *calcaneus* (*os calcis*) is the long, arched heel-bone, the posterior extremity of which rests upon the ground. The tendo calcaneus inserts on the medial part of the tubercle of the calcaneus, which is a considerable distance behind the articular surface for the talus. This arrangement is designed to give great leverage for the action of the calcaneal tendon. The calcaneus articulates anteriorly with the cuboid. On the mesial margin of the calcaneus the shelflike sustentaculum tali juts out to support part of the neck of the talus and to serve as an attachment for the plantar calcaneonavicular (spring) ligament. This ligament is strong and supports part of the head of the talus and that part of the body weight transmitted to it.

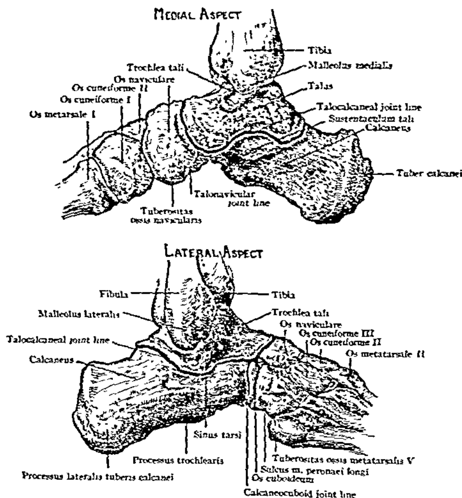


Fig. 1031. Medial and lateral views of the talocalcaneonavicular (subastragaloid) joint.

Action	Joints Involved	Muscles		
Dorsiflexion	Talocrural (ankle joint)	Tibialis anterior Peroneus tertius	Extensor digitorum longus Extensor hallucis longus	
Plantarflexion	Talocrural (ankle joint)	Gastrocnemius Soleus Plantaris	Tibialis posterior Peroneus brevis Peroneus longus	Flexor digitorum longus Flexor hallucis longus
Adduction	Midtarsal	Tibialis posterior and anterior		
Abduction	Midtarsal	Peroneus longus, brevis and tertius		
Inversion	Subastragaloid	Tibialis anterior and tibialis posterior		
Eversion	Subastragaloid	Peroneus tertius, brevis and longus		

veyed through the neck and head of the talus.

Although all the joints of the foot act to some degree in all movements of the foot, single joints permit the cardinal motions. The table above indicates the motion of the foot, the muscles producing them, and the joints in which they occur.

PLANTAR VESSELS AND NERVES. The posterior tibial artery divides into the lateral and medial plantar arteries at the distal border of the laciniate (internal annular) ligament, midway between the medial malleolus and the most prominent part of the mesial surface of the calcaneus. From this midpoint the *medial plantar artery*, usually a small vessel, passes forward between the abductor hallucis and the flexor digitorum brevis muscles (Fig. 1028). Its terminal branches join the digital arteries. The *lateral plantar artery* runs deep to the flexor digitorum muscle, anterior and lateral to the base of the fifth metatarsal, where it bends sharply mesially and becomes the *plantar arch*, which extends over the bases of the three middle metatarsals. It can be ligated through an incision at the mesial side of the base of the fifth metatarsal, where it lies between the flexor digitorum brevis and the abductor digiti quinti muscles.

Hemorrhage from the plantar arteries can usually be arrested by packing the wound, applying pressure, and elevating the leg. Care must be exercised in making deep incisions in the groove to the medial and lateral sides of the flexor digitorum brevis muscle, for fear of wounding these arteries. They are not endangered in subcutaneous operations on the plantar aponeurosis, because this structure is superficial to the flexor brevis muscle and the arteries are deep to that muscle.

The *medial plantar nerve* (L 4, 5; S 1) arises from the tibial nerve under the laciniate (internal annular) ligament and runs forward with the medial plantar artery (Fig. 1028). The *lateral plantar nerve* supplies most of the muscles of the sole.

PLANTAR ABSCESS. Plantar abscesses usually result from infected puncture wounds or from upward extension from infection in the webs of the toes (Fig. 1030). The strong central portion of the plantar aponeurosis overlies and gives origin to the flexor digitorum brevis muscles. A puncture wound penetrating the aponeurosis may enter, but not traverse, the underlying short flexor, so that the tendons of the long flexors escape. Infection arising in this wound may form a *superficial plantar abscess*, from which pus points in several directions. The pus may come directly through gaps in the plantar aponeurosis and form an hourglass or collar-button abscess, part lying deep to the aponeurosis in the substance of the flexor brevis and part in the subcutaneous tissue; it may burrow forward between the slips of the plantar fascia in the direction of the webs of the toes; it may appear in the groove on the outer part of the sole between the flexor brevis and the abductor digiti quinti muscles; or it may appear in the groove on the medial side of the foot between the abductor hallucis and the flexor brevis muscle.

The pus in a *deep plantar abscess* accumulates beneath the flexor brevis muscle and about the deep flexor tendons. It tends to pass up the leg along the flexor tendon, but may present in the webs of the toes or in the groove, to one side or the other of the flexor brevis muscle.

After *incision* of the skin and division of the plantar aponeurosis the abscess may be located and evacuated by blunt hemostat dissection which avoids wounding arteries. Incisions should not be made over weight-bearing areas; hence incision on the metatarsal heads and on the lateral border of the sole is avoided.

Bones and Joints of the Foot

The numerous bones and joints of the foot endow it with mobility and a capacity for lessening shock. If the bones become anky-

removed and in which the connecting ligaments and tendon insertions are preserved. The plantar surface appears dome-shaped with a well defined arch extending anteroposteriorly, and a less highly developed arch crossing the foot from side to side.

The nature and extent of the LONGITUDINAL ARCH are displayed best by resting the foot on a flat surface. Its height and length are greatest at the mesial border of the foot and diminish laterally until, at the lateral margin, the arch has almost disappeared. The arch is made up of medial and lateral columns. The *medial column* is more important and consists of the calcaneus, talus, navicular, the three cuneiforms and the three medial metatarsals (Figs. 1032, 1034). The *lateral column* consists of the calcaneus, the cuboid and the two outer metatarsals (Fig. 1033). This column is low and rests on the ground.

The body of the talus rests upon the calcaneus, and its head on the inferior calcaneonavicular (spring) ligament. When the spring ligament is stretched, the head of the talus presses downward and medially, causing stretching of the mesial component of the arch with lengthening and flattening of the foot. The front of the foot turns outward into eversion (pronation), and the medial malleolus becomes prominent. In general, inverting and adducting movements of the foot raise and strengthen the arch, while everting and abducting movements lower and weaken it.

The TRANSVERSE ARCH owes its existence to the wedge-shaped formation of certain of its bones, especially the middle and lateral cuneiforms and the second, third and fourth metatarsal bones. Their broad surfaces are directed toward the dorsum of the foot, and their narrow surfaces toward the plantar aspect. This arch is relatively high and narrow in the middle of the foot, where the wedge-shaped middle and lateral cuneiforms are strong. The forward part of the arch is broad, flat and weak. It often gives way, letting down one or more of the metatarsal heads, beneath which painful calluses form.

LIGAMENTOUS AND MUSCULAR SUPPORT OF THE ARCHES OF THE FOOT. In maintaining the arches of the foot, the LIGAMENTS of the tarsus and the metatarsus play an important role. The most essential ligaments are the plantar calcaneonavicular, the long plantar and the plantar calcaneocuboid (short plantar). They are reinforced by the strong plantar fascia, which stretches like a tight cord from one extremity of the long bony arch to the other (Fig. 1034). The ligaments act only as passive agents, in contrast to the muscles which take an active part and are indispensable for the maintenance of the proper shape of the arch. Because of the elasticity of the ligamentous apparatus, the arches flatten out when the foot has to sustain a heavy weight, but they regain their original shape immediately when the weight is removed.

The *plantar calcaneonavicular* (*spring*) *ligament* stretches from the anterior border of the sustentaculum tali of the calcaneus to the plantar surface of the navicular bone. It is a strong fibrocartilaginous band blending with the deltoid (internal lateral) ligament of the ankle joint. With the posterior articular surface of the navicular, it forms a pocket for the head of the talus.

The *long plantar ligament* is a powerful structure attached to the under surface of the calcaneus and to the ridge on the inferior surface of the cuboid, whence it continues forward to the bases of the second, third and fourth metatarsal bones. The *plantar calcaneocuboid* (*short plantar*) *ligament* runs obliquely forward and medially from the under surface of the calcaneus to the posterior part of the cuboid, where it is concealed by the long plantar ligament, which separates the two bones. The support of the transverse arch is maintained by the plantar intertarsal and tarsometatarsal ligaments.

The MUSCULAR SUPPORT of the longitudinal arch is derived from the strong tendons of the tibialis anterior, tibialis posterior, flexor digitorum longus and brevis, and the flexor hallucis longus (Fig. 1034). The principal muscle supporting the transverse arch is the peroneus longus, the tendon of which stretches across the arch like a bowstring and acts to apt proximate its extremities. Additional suppor- comes from the tendinous sling, formed by the crossing of the flexor digitorum longus and the flexor hallucis longus tendons and from slips from the tibialis posterior which tend to contract the arch.

Surgical Considerations

The causes for alteration in the anatomic relationship of the structures of the foot are many and require careful analysis for proper correction. Any disturbance in muscle equilibrium results in distortion and deformity,

The *talus* (*astragalus*) is described on page 1075. Its body is rounded anteroposteriorly to articulate with the tibia, and its sides are grasped by the malleoli. The inferior surface of its body articulates with the calcaneus. The head of the talus is thrust forward on a short neck to articulate with the navicular anteriorly and the plantar calcaneonavicular ligament inferiorly. The *navicular* (*scaphoid*) receives the forward thrust from the talus in weight-bearing and transmits it to the three cuneiforms in front. The tubercle of the navicular is a prominent landmark. The *cuboid* and *cuneiforms* rarely are involved surgically.

Of the *metatarsals*, the first is short, strong, and of greater importance in weight-bearing. Its joints are long and solid. Between it and the ground are two sesamoid bones. The base of the fifth metatarsal is proximal to the main metatarsal joint line and is a prominent landmark on the outer margin of the foot.

The slight impairment of the function of the foot and the slight loss of firmness and stability consequent upon removal of some of its bony elements are remarkable. The talus may be removed completely without causing serious disability. The navicular, the neck of the talus, and the first and second cuneiform bones have been resected with good results. It is not desirable to interfere with the calcaneus, because of its importance as a base of support and its attachments to important ligaments and muscles.

At birth, *centers of ossification* are present in the talus, calcaneus and cuboid bones. The lateral cuneiform ossifies during the first year, the medial during the second, and the middle cuneiform and navicular during the third or fourth year. A secondary center for the calcaneus appears in the eighth year in the posterior cartilaginous extremity of the bone, and forms an epiphysis which unites with the main bone between the sixteenth and twentieth years. A separate center for the posterior tubercle of the talus sometimes is present and remains separate; it is known as the os trigonum. Each of the metatarsals has a single epiphysis which appears during the third year and is united to the diaphysis during the eighteenth year. In the first metatarsal the epiphysis forms the base of the bone, but in all the others it forms the rounded head of the bone. The ossification of the phalanges is similar to that of the first metatarsal.

JOINTS AND LIGAMENTS OF THE FOOT. The extent of movement in the foot is less than would be expected, considering the number of joints. Only in the talocalcaneal and the talonavicular joints does any considerable movement take place. The little lateral motion present occurs principally at the calcaneocuboid and talonavicular joints, which lie in the same plane and form the midtarsal joint. The many smaller joints enhance flexibility and, in the aggregate, permit a fair degree of motion.

The TALOCALCANEONAVICULAR (SUBASTRAGALOID) JOINT is a large region of articulation between the talus above and the calcaneus and navicular below and in front. The talus is not a keystone bone and is not wedged in between the calcaneus and navicular. It allows the foot to play freely beneath it. In the talocalcaneal segment the under surface of the talus articulates with anterior and posterior facets of the calcaneus, which are distinct from each other. The anterior talocalcaneal joint is continuous with the talonavicular joint. The two parts of the joint are separated by the powerful interosseous talocalcaneal ligament, which is the main bond of union between the talus and calcaneus and partially fills the obliquely directed groove (tarsal sinus) which passes between these bones. The removal of the areolovascular tissue, which also occupies this cleft, is an important step in arthrodesis. The remaining ligaments investing the joint on its peripheral aspect are weak. They are reinforced to some extent by the deltoid and lateral ligaments of the ankle joint (p. 1079). The *talonavicular segment* of the joint is of the ball-and-socket variety. In it the convex head of the talus articulates with the concave facet on the posterior aspect of the navicular, while the lower part of the head of the talus articulates with the plantar calcaneonavicular (spring) ligament, which plays a large role in maintaining the integrity of the arch.

The MIDTARSAL JOINT (of Chopart) has two divisions, the *talonavicular* portion of the subtaloid joint, and the *calcaneocuboid joint*. In the latter the apposing bony surfaces present a concavoconvex outline. The midtarsal joint is supported by the long and short plantar ligaments, which separate the posterior and anterior parts of the foot.

ARCHED STRUCTURE OF THE FOOT. The clearest conception of the arched structure of the foot is obtained from examining a well-shaped specimen from which the tissues have been

because the muscles, which ordinarily are balanced in tension, are not opposed, and draw structures toward the uninvolved side. Upset of the delicately balanced muscle mechanism may occur from injury, fracture, dislocation or paralysis. In spastic birth palsies the muscles are contracted, and in anterior horn cell degeneration they are flaccid. Deformity also results when the bones and ligaments are affected, because the arch construction of the foot gives way. This type of deformity obtains in rickets, gout and tuberculosis. The foot sometimes is weakened without apparent cause.

Flatfoot, Pronated Foot. The arches of the foot show considerable variability in different persons. In some the arches are well developed, and in others, so poorly developed as to be almost absent. In infants the arches are poorly developed, and the sole of the foot is almost flat. The subsequent arch development proceeds with the general growth of the foot. In some races—the Negro, for example—the arching never assumes striking proportions. A departure from the so-called normal shape of foot may appear as a deformity, but present no real pathologic change and cause no pain. Deformity is in no wise as important as functional disability.

If impressions of a foot with a well developed arch are studied, the area of contact is found to vary much in accordance with the amount of pressure brought to bear on the foot. In withstanding heavy pressure, the arches flatten, and the foot lengthens and broadens. Foot strain causes the anterior pillar of the longitudinal arch to deviate outward. Most of the *movement takes place at the midtarsal joint*, and the head of the talus becomes more prominent on the medial margin of the foot.

If the foot has assumed the position of complete pronation (pes planus), the entire medial aspect of the sole from the great toe to the heel lies in contact with the ground (Fig. 1035).

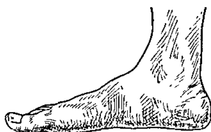


Fig. 1035. PES PLANUS (FLATFOOT).

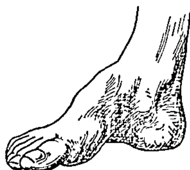


Fig. 1036. PES CAVUS.

The long axis of the talus is directed definitely medially, and the head and tubercle of the navicular project prominently on the medial border. The normal slight concavity of the medial border is changed to a definite convexity. The medial malleolus is unduly prominent. The lateral border of the foot is raised slightly from the ground. The calcaneus, instead of resting squarely on the ground, is everted, bringing its lateral surface into direct contact with the extremity of the lateral malleolus, even to the degree of articulation by two lateral facets. This condition transmits a great part of the superincumbent weight to the calcaneus through the lateral malleolus.

The factors entering into the causation of acquired flatfoot are many. Debilitating illnesses, improper shoes and improper posture, and weakening and relaxation of the ligaments and loss of tone in the muscles whose tendons maintain the arches predispose to this condition. The tendency for its development is augmented when the foot is subjected to increased or prolonged strain, such as occurs in a *rapid increase in body weight, unaccustomed* standing for long periods, and carrying heavy loads.

The pain in a pronated foot is not necessarily confined to the foot, but may occur in the knee or even in the back. The pain, commonly referred to the medial side of the foot, may pass readily to the medial side of the knee, for, as the body weight falls farther to the medial side of the foot, strain is put on the tibial collateral (internal lateral) ligament of the knee joint. Painful calluses develop over pressure points on bony prominences of the foot which are not intended to touch the ground.

In the *treatment* of painfully pronated feet the arches are supported by padding or bracing. The heels of the shoes are raised on the

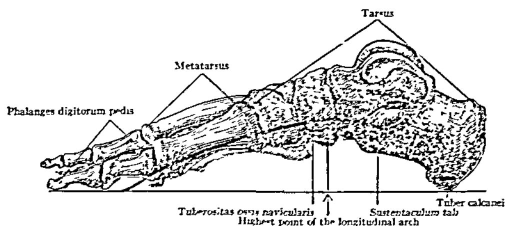


Fig. 1032. MEDIAL COLUMN OF THE LONGITUDINAL ARCH OF THE FOOT.

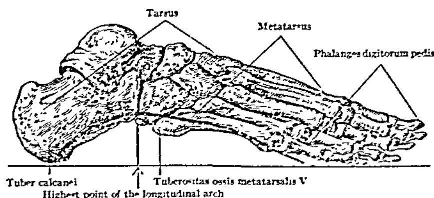


Fig. 1033. LATERAL COLUMN OF THE LONGITUDINAL ARCH OF THE FOOT.

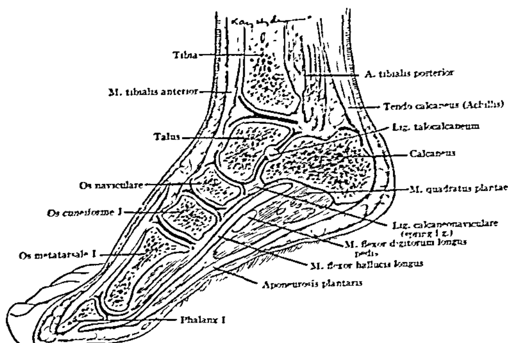


Fig. 1034. SAGITTAL SECTION THROUGH THE MEDIAL COLUMN OF THE LONGITUDINAL ARCH OF THE RIGHT FOOT TO SHOW THE PLANTAR CALCANEONAVICULAR (SPRING) LIGAMENT.

of the calf group of muscles and of the forefoot is absent. A large fat pad develops beneath the heel.

A varus or valgus position may be superimposed upon this deformity, with or without modification of the arches. In *talipes calcaneovarus* the hollow of the foot generally is exaggerated because of the pull of the tibialis anterior and posterior muscles upon the long arch of the foot. The drawing of the pillars together by the flexor digitorum brevis muscle causes the arch to ascend and the plantar ligaments to contract. In *talipes calcaneovalgus* the arch is lowered.

When the deformity is *congenital*, the tendons of the muscles of the anterior compartment of the leg are contracted, while those of the posterior compartment are overstretched. When the deformity is *acquired*, it results from the unopposed action of the anterior leg muscles.

Talipes calcaneus is the most disabling and resistant acquired foot deformity. Correction of this condition is difficult and may require transplantation of the tibialis anticus and peroneus longus into the posterior tip of the os calcis and Achilles tendon and, in addition, a triple arthrodesis or possibly even a panastragalar arthrodesis.

TALIPES VALGUS. In talipes valgus the lateral border of the foot is raised, and the medial border is depressed into contact with the ground (Fig. 1039). When the condition is *congenital*, the peronei are shortened, and the two tibialis muscles are overstretched. The *acquired* form is caused by paralysis of the tibialis anterior and posterior muscles. In the combined varieties the muscles of more than one compartment of the leg are involved. In the *treatment* of minor deformities of the congenital type, manipulation to overcorrect the faulty position and the use of a splint to maintain the correction may suffice. In a more pronounced deformity, manipulations must be more vigorous, and plastic lengthening of the shortened structures may be necessary before the foot can be wrenched into proper position. In advanced cases osteotomy and arthrodesis through the midtarsal and subastragaloid joints are required to align and stabilize the foot.

TALIPES VARUS. The deformity of talipes varus is one of adduction and inversion (Fig. 1040). The foot is twisted upon itself at the midtarsal joint; in consequence, the concavity of the foot is increased along its upwardly directed medial border and becomes more convex along its dorsum and its lateral aspect. In walking, the dorsum of the foot is directed forward and the sole backward. Talipes varus is rarely met with alone; it is associated most often with talipes equinus. This combination constitutes by far the commonest of all clubfoot deformities.

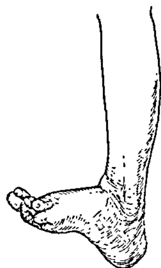


Fig. 1038. TALIPES CALCANEUS.

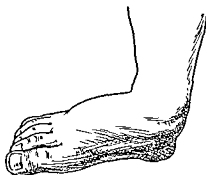


Fig. 1039. TALIPES VALGUS.



Fig. 1040. TALIPES VARUS.

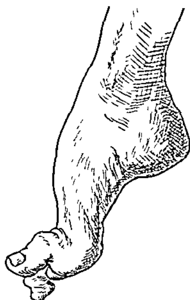


Fig. 1037. TALIPES EQUINUS.

mesial side (Thomas heel). When pain is relieved, exercises are instituted, based on the tendency of adduction, inversion and supination, to strengthen the muscle supports of the foot. The transverse arch may be strengthened by flexion movements of the toes.

Talipes in General. The deformities of the foot are grouped under the heading of talipes. The common foot deformities are those in which the affected parts are turned to an abnormal degree in the direction of their normal movements. Most of these deformities are *congenital*, but a great many are *acquired*, and present at various periods after birth. It is not always easy to separate the two varieties. Congenital deformities need to be differentiated from similar-appearing deformities which may have been caused by other conditions, such as spina bifida, cerebral palsy, poliomyelitis or other neurological conditions.

A deformed foot usually presents two associated characteristics—paralysis or weakness, and contracture or strength. Paralysis can occur without contracture, but the muscle system functions on the principle of balance, and eventually the paralyzed muscle or muscle group is overpowered by the opposing muscles, which then produce contracture. Similarly, if contracture is the more prominent and perhaps the primary element, the opposing muscles and ligaments must, in time, be weakened and stretched.

Recognition of the shift of muscle balance furnishes the proper rationale for treatment. If weakness of the foot muscles predominates, support and even tendon transplantation and arthrodesis are required. If contracture is present, operation to weaken the stronger tissues and forcible manipulative measures are used. A contracture may be overcome and the foot be brought to a normal position, but function cannot be normal until the overstretched tissues have regained their tone.

There are four simple forms of talipes—equinus, calcaneus, valgus and varus (Figs. 1037 to 1040). Combinations of these forms are common.

Talipes Equinus. In talipes equinus, the simple form of which is rarely congenital, the tendo calcaneus is contracted and nonyielding, and prevents the foot from being placed squarely on the ground (Fig. 1037). The balls of the toes contact the ground, so that, in walking, the toes are at a right angle to the foot. In advanced equinus the foot may form an almost straight line with the leg. A contracture of the plantar aponeurosis is a frequent secondary occurrence which leads to an accentuation of the dorsal convexity of the foot with a deep hollow of the sole (talipes cavus). If adduction and inversion are superimposed on an equinus deformity, the condition is known as *talipes equinovarus*. If abduction and eversion are superimposed, the condition is *talipes equinovalgus*.

In congenital talipes equinus the posterior muscles and the plantar aponeurosis are shortened secondarily to congenital malformation. In acquired talipes equinus the posterior leg muscles enter into unopposed contracture because of paresis or paralysis of the anterior leg muscles. Treatment consists in stretching the calf muscles or performing a tenotomy upon the Achilles tendon.

Talipes Calcaneus. Acute flexion of the foot on the leg constitutes the rare form of talipes calcaneus (Fig. 1038), which is usually secondary to infantile paralysis involving the calf muscles. The dorsiflexion of the foot at the ankle may be of such a degree that the foot and leg lie against each other. In the more common form of talipes calcaneus there is partial or complete paralysis of all the muscles which act upon the foot (flatfoot). In this condition the calcaneus and talus are in dorsiflexion. The remaining tarsal bones and the forward part of the foot are plantar-flexed by the contracture of the plantar structures. The typical gait is pounding, because the protecting spring action

minution, the fracture may be overlooked unless roentgenograms are taken in a posterior view with the patient prone, in order to reveal the exact condition of the bone. In many instances the presence of a comminuted fracture is indicated by a lessening of the vertical and an increase in the transverse diameter of the heel. In radiological examinations the presence of the os trigonum and the calcaneal epiphysis must be kept in mind.

In the production of compressed and comminuted fractures the talus, which is held tightly within the tibiofibular mortise, suddenly strikes the calcaneus. The wedge-shaped inferior surface of the talus fractures the calcaneus longitudinally and transversely. The calcaneus is widened, often to twice its normal width, and is definitely shortened.

In the normal foot the angle subtended by the dorsal projection of the line of the posterior articular surfaces of the calcaneus and the plane of the superior surface of the body of the calcaneus measures from 27 to 33 degrees. When the calcaneus is fractured, the heel may be so crumpled that its arched shape is broken and becomes horizontal; this angle then becomes smaller or disappears (Fig. 1041). The tuberosity of the calcaneus may even be elevated above the line of the posterior projection of the posterior articular surfaces. The upward displacement of the fragment which holds the tuberosity is maintained by the traction of the Achilles tendon. The widening and shortening displacement is maintained by the intrinsic plantar muscles of the foot. The pull of these two muscle groups can be overcome only by traction in a direction opposite to the combined actions of the opposing muscles. By exerting traction along the axis of the normal calcaneus, both displacements can be remedied. The widening of the bone can be corrected by adequate lateral pressure on both sides. This fracture is severe and frequently seriously disrupts the subastragalar joint, causing a traumatic arthritis. A triple arthrodesis is frequently necessary.

Dislocation and Fracture of the Metatarsal Bones. There is little likelihood of *dislocation* of the metatarsals, because of their attachment to the tarsus at different levels and the security with which they are bound up with the transverse arch of the foot. In a severe injury, however, one or more may be fractured near the proximal end, and the distal fragments be displaced laterally and forward. The fifth metatarsal may be fractured near its proximal end, or its prominent tuberosity may be torn away by violent eversion of the foot. *Fractures* of the shaft sometimes occur from curiously trivial causes, such as the sudden assumption of a heavy load.

Plaster immobilization is the *treatment* for fractures without displacement. Displacements are corrected by manipulation, and the proper position is maintained by immobilization in plaster.

Tarsal Dislocations. In dislocation at the talocalcaneonavicular joint the talus maintains normal relation to the malleoli. In the commonest form the foot is dislocated posteriorly, and the talus overrides the navicular. If the ligaments binding the talus to the cal-

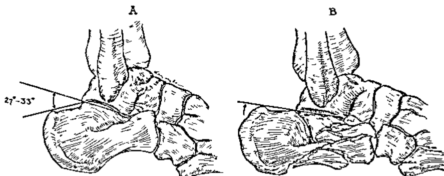


Fig. 1041. FRACTURE OF THE CALCANEUS AND CALCANEAL ANGLE.

A, The normal relations between the talus and calcaneus are indicated. Attention is directed to the posterior continuation of a line parallel with the posterior articular surface of the talocalcaneal joint. This line makes a small angle with a line parallel to the superior surface of the body of the calcaneus. *B*, The calcaneus is fractured. The posterior continuation of the articular line coincides with the line along the superior surface of the calcaneus. The angle normally present between the 2 lines is obliterated

In the *congenital* variety the tendons of the tibialis muscles and the deltoid ligament are shortened. The distal end of the tibial shaft is often twisted medially. In the *acquired* variety there is overcontraction of the tibialis muscles against the paralyzed peroneus longus or brevis muscles.

The tibialis tendons may require lengthening or transplantation to prevent their drawing the foot medially; division of the plantar fascia and the deltoid ligament is often necessary. To strengthen the abducting mechanism, the tendon of the tibialis anterior is detached and transplanted from the medial to the lateral side of the foot. When the abductor muscles are paralyzed completely, the tibialis anterior tendon is transplanted to the center of the dorsum of the foot, and the tibialis posterior tendon is transplanted to the insertion of the Achilles tendon into the calcaneus; additionally, arthrodesis of the subastragaloid joint frequently is required.

Talipes Equinovarus. In talipes equinovarus the heel is elevated, and the foot is adducted and inverted so that its medial border looks upward, and its lateral margin downward. The whole foot is bent upon itself. There is, in addition, medial rotation of the tibia or even of the entire lower extremity. This rotation may be estimated readily by noticing the direction of the plane of the anterior aspect of the patella and comparing it with the line uniting the tips of the malleoli.

The deformity may be caused by the persistence of the attitude which the foot assumes in early uterine life, or by retarded development. If treated early, the condition usually can be corrected by manipulation and immobilization of the foot in the position of calcaneovalgus. Many elements conspire to render the foot rigid in the deformed condition. The deltoid and inferior calcaneonavicular ligaments on the medial aspect of the foot become contracted, and the tendons of the leg muscles, especially those of the tibialis anterior, the calf group and the flexor digitorum longus, are shortened. Contracture takes place in the plantar aponeurosis and even in the skin of the sole. There is often an alteration in the shape of the bones and in the direction of their articular processes. The talus is modified strikingly, and its neck deviates inward. The calcaneus becomes curved until its medial surface is concave and its lateral surface convex. The dorsal aspect of the cuboid presses upon the ground, and the overlying skin becomes hard and horny.

Fractures of the Talus and Navicular. The tarsal bones, because of their cancellous structure, yield readily to direct and indirect injury. Fracture occurs commonly in falls from a height upon the feet. An open fracture is a frequent complication from crushing injuries to the scantily protected dorsum of the foot.

The neck of the *talus* may be broken transversely or obliquely, with a resulting displacement of the foot laterally into a painful valgus position. Treatment of this fracture consists in remolding the foot properly and retaining it in plaster. When the body of the talus is crushed, the deformity cannot be corrected, and immobilization or even excision is required. Talus fractures cause considerable limitation of motion at the ankle joint. The posterior process of the talus, the os trigonum, sometimes is an independent bone connected to the body of the main bone by fibrous tissue; in a roentgenogram it may be mistaken for a fracture.

Navicular fracture occurs occasionally; it results from landing on the toes in a fall from a height. The acting force is the downward thrust of the talus against the resistance of the anterior part of the foot, in which the navicular is compressed against the cuneiforms. The mushrooming results in a bony prominence on the dorsum of the foot. Treatment consists in careful manipulation, remolding, and fixation of the long arch. A more common fracture of the navicular is a sprain fracture of the dorsal surface, caused by forced plantar flexion. Fixation in dorsiflexion usually is sufficient treatment. Occasionally a bony process at the tuberosity of the navicular (os tibiale externum) fails to unite with the main bone and may be mistaken for a fracture.

Fracture of the Calcaneus. Fracture of the calcaneus is the commonest fracture in the tarsus, and frequently is bilateral. It occurs usually in falling or jumping from a height and alighting upon the heel. The fracture almost always is comminuted and involves the joints; even with extensive comminution the degree of deformity need not be great. In a severe fracture the transverse diameter of the foot is increased palpably because of the lateral spread of the fragments, even to the levels of the malleoli. All motions of abduction and adduction are restricted. If there is little com-

care to obtain a good end-weight-bearing stump.

TRANSMETATARSAL AMPUTATION. Good results following transmetatarsal amputation (Fig. 1043) for ischemic gangrene and infection were first reported by McKittrick in 1946. Most cases are associated with arteriosclerosis and diabetes, and the main indication is well demarcated gangrene of one or more toes, with infection pretty well controlled by antibiotics. Absence of a line of demarcation usually indicates a spreading process and should be considered a contraindication to this procedure. In cases involving the first and fifth toes, single toe amputations may be carried out with a reasonable chance of success, but the trans-*metatarsal amputation is safer, particularly* when more than one toe is involved.

TUBERCULOSIS OF THE TARSUS. Tuberculosis of the tarsus is common, and usually appears as a rarefying osteitis (caries) in one or another of the bones. One of the determining factors may be the preponderance of poorly vascularized cancellous bone. It would appear that the bones most subject to disease are those which bear the greatest strain: the calcaneus, navicular, cuboid, the base of the first metatarsal and, less frequently, the talus. The disease, however, may involve the tarsus *en masse*. Tuberculosis of the calcaneus tends to remain localized in the posterior half of the bone. The lesion sometimes is represented by several abscesses surrounded by sclerosed bone. As the process advances, it invades the neighboring talocalcaneal or the calcaneocuboid joint.

Tuberculosis beginning in the neck of the talus may spread upward and involve the synovial membrane of the ankle joint; backward and infect the body of the bone, whence it spreads through the articular cartilage upward into the ankle joint; downward to the talocalcaneal joint; or forward into the talonavicular joint. Caries of the navicular is serious, since it may involve the complex synovial membrane of the anterior part of the foot.

The signs of tarsal tuberculosis, especially when the forward part of the foot is involved, usually are most evident upon the dorsum and sides of the foot, because these areas are covered thinly. The heel and toes remain essentially unchanged, but the intervening area is swollen. The skin over the dorsum has a glazed appearance and may present the openings of many sinuses.

Caries of the tarsal bones and joints may extend through the periosteum and the joint coverings and into the synovial tendon sheaths, especially those of the tibialis and the peroneus muscles, rendering treatment complicated.

RECONSTRUCTIVE SURGERY. The foot presents a variety of faulty functional positions, for which reconstructive surgical procedures must be instituted to satisfy the cardinal requirements of painless function and to give as much mobility as is compatible with stability.

In localized paralyses *tendon lengthening*, *shortening* and *transplantation* are performed. Tendons for transplantation must have normal tone and functional integrity. The normal *tendon may be inserted subperiosteally to a* fresh attachment on bone, or be sutured to other normal tendons, but never to paralyzed ones.

The joints, in a variety of paralytic conditions, must be obliterated to secure stability. In the foot the outstanding *arthrodeses* immobilize the talocalcaneonavicular (subastragaloid), talonavicular and calcaneocuboid (midtarsal) joints, where much of the normal movement of the foot occurs. If bony deformity accompanies instability, wedges of bone are removed from denuded joint surfaces in such a manner as to restore the weight-bearing lines of the foot. Finally, the whole foot is set backward through the subastragaloid joint to bring the weight more nearly over the longitudinal arch. Another recognized form of stabilization is *astragalectomy*. Arthrodesis and astragalectomy may be performed through Kocher's lateral J-shaped incision at the ankle (p. 1084). In severe or neglected paralytic foot deformities of the acquired type external tibial torsion regularly is present, and requires correction by tibial *osteotomy*.

In certain types of deformity, particularly congenital talipes equinovarus, a wedge of tarsus may be removed to restore balance to the foot (*cuneiform tarsectomy*). In equinus deformities of the drop foot or flatfoot type a wedge of bone may be elevated from the dorsal surface of the calcaneus between the Achilles tendon and the back of the ankle so as to impinge upon the tibia and limit plantar flexion (*bone-block*).

Toes

The toes are prehensile structures which are of no great use to man, although they aid

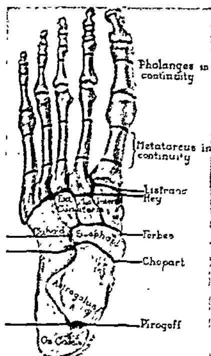


Fig. 1042. SKELETAL LINES OF EXCISION FOR AMPUTATIONS OF THE FOOT AND ANKLE.
(From Orr: Operations of General Surgery.)

caneus rupture, the calcaneus is allowed to thrust backward. The foot may be dislocated to either side as well as forward, but usually only with associated fractures. Midtarsal dislocations at the talonavicular and calcaneocuboid joints are rare and are part of crushing compound injuries.

Amputations of the Foot and Ankle. These operations are often done, and the sites of election are well established (Fig. 1042). The usual indications are injuries, or gangrene due to peripheral vascular deficiency resulting most commonly from arteriosclerosis or thromboangiitis obliterans. Every amputation should be considered under the factors of satisfactory healing, locomotion and weight-bearing.

Toes are removed with long plantar flaps closed without tension. Disarticulations at the metatarsophalangeal joints are done with lateral flaps, and commonly the cartilage is removed from the end of the metatarsal, or its head is excised. A single toe, even the great toe, should seldom be left alone, because it frequently becomes deformed, particularly for the vascular-deficient group, has unusual pressures upon it, and causes trouble. With present or impending gangrene, amputation of toes is a precarious procedure, the wound often failing to heal or the gangrenous process spreading to the forefoot, all necessitating a higher amputation later.

In dealing with arteriosclerotic gangrene and infection of the toes, the *Lisfranc amputation* (Fig. 1042) has also been done on a few patients with diabetic gangrene, with fair success. Proximal to this point the Syme amputation (Fig. 1027) is the only foot and ankle amputation of value, and needs to be done with great



Fig. 1043. TRANSMETATARSAL AMPUTATION FOR ISCHEMIC GANGRENE.
a, Dorsal, plantar and medial views of the lines of skin incision. *b*, A short dorsal and long plantar flap provides a good covering of the forefoot. (From Haimovici: Arch. Surg., 70: 45–51, 1955.)

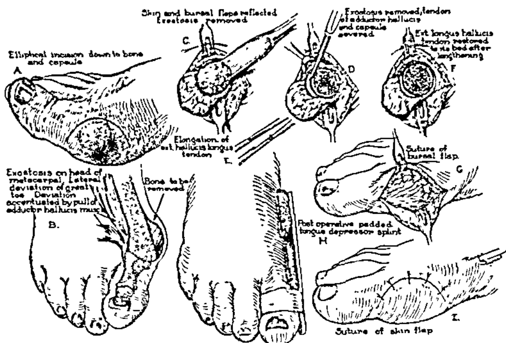


Fig. 1045. OPERATIVE CORRECTION OF HALLUX VALGUS.

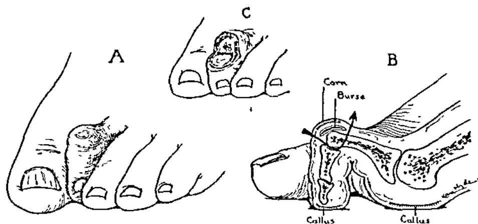


Fig. 1046. FRONT VIEW AND SCHEMATIC SAGITTAL SECTION OF A HAMMER TOE.

The arrow in *B* indicates the excision of the prominent head of the proximal phalanx; this is necessary to shorten the toe and allow it to be straightened out. *C*, Shows the method of removal of the head of the proximal phalanx.

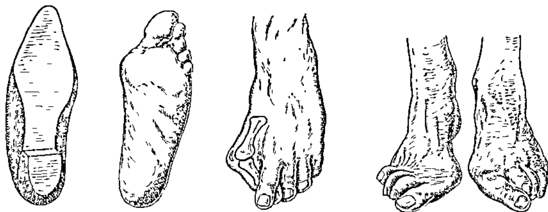


Fig. 1044. HALLUX VALGUS.

considerably in walking and to a greater degree in balancing, climbing and running. They increase the efficiency of the foot, but their loss impairs it to no great degree. Intricate and delicate movements are hindered by their loss, but the firmer and more deliberate movements of walking remain nearly normal. The great toe with its two instead of three phalanges acquires strength at the expense of mobility.

HALLUX VALGUS. In hallux valgus the great toe deviates laterally to an abnormal extent, rendering the head of the first metatarsal prominent (Fig. 1044). This abnormal relationship produces an unsightly, angular projection which commonly is exaggerated by the development of osteophytic overgrowths upon the metatarsal head. In hallux valgus there is usually a deformity of the head of the metatarsal in which the joint surface is inclined obliquely laterally. Congenital metatarsus varus frequently may be the etiologic factor. In general, the condition is thought to be occasioned by ill-fitting shoes. Such shoes, besides being too short, have the axis of the toe of the shoe in line with the third rather than with the first toe. The shoe thus squeezes the toes against one another and displaces the great toe laterally. The distortion is increased by the action of the long flexor, extensor and adductor muscles. These muscles and the lateral metacarpophalangeal ligament may become permanently shortened.

An adventitious bursa, known as a *bunion*, is likely to develop over the projecting head of the first metatarsal, further accentuating the deformity. This bursa is irritated constantly by pressure and friction, and infection in it may involve the metatarsophalangeal joint.

Operations designed to cure hallux valgus contemplate reducing the prominence of the metatarsal head by removal of a large part of its medial surface and reconstruction of its articulating surface, so that the phalanx may be brought into proper alignment (Fig. 1045). A curved incision with the concavity toward the sole is made over the prominence of the joint, and the flap of skin and fascia is retracted downward. The bursa is dissected free, save for its proximal attachment, so that it can be stitched into position between the phalanx and the remodelled metatarsal head. To correct the alignment of the toe, the abductor hallucis tendon, which had been shifted plantarly, is now reinserted into a medial position of the proximal phalanx of the big toe. The adductor hallucis tendon is sectioned to relieve its deforming pull. The toe is then maintained in this position by corrective and supportive bandaging for four weeks. Many operations are described to correct this deformity.

HAMMER TOE. A hammer toe is one contracted into sharp angulation (Fig. 1046). The contraction usually occurs in the second or third toe, and may be present alone or in combination with hallux valgus. When it affects the four lateral digits of each foot, it commonly is congenital in origin. All the toes tend toward this contracture in the presence of pes cavus or equinus. In these conditions the common extensor muscle is stretched, elevating the proximal phalanx, but leaving the other phalanges in flexion. In the typical deformity the metatarsophalangeal joint and the distal interphalangeal joint are hyperextended, but the proximal interphalangeal joint is flexed acutely. Over the acutely flexed joint, and occasionally upon the tip of the toe, a painful corn develops.

In the *operative treatment* of this condition

toe the soft parts have a natural tendency to crowd around the borders of the nail. Pressure from the sole upward or from above downward causes the nail margin to impinge upon and possibly cut into the flesh until ulceration and, later, infection set in. The pressure of a badly shaped shoe may be responsible. *In mild cases* the cuticle encroaches upon the nail; in advanced cases the skin of the nail bed is inflamed, thickened and overhanging, and is the seat of suppurative exuberant granulation. The pain is intense, and the discharge is foul.

In the *treatment* of mild cases a wisp of antiseptic cotton placed under the offending edge of the nail usually suffices to clear up the condition. In severer cases permanent relief can be obtained by *excising the lateral fourth* of the nail with the nail bed and matrix. Some surgeons also remove a small portion of the adjacent skin fold (see Fig. 1047).

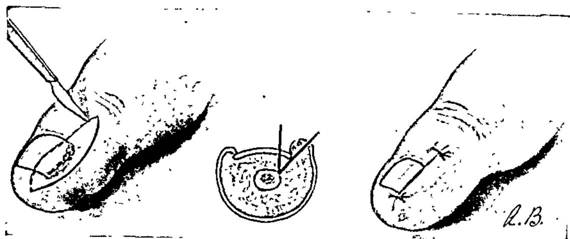


Fig. 1047. METHOD OF EXCISING AN INGROWN TOENAIL.

Left, An incision is made through the nail and nail bed, then through the skin over the nail matrix and the matrix itself. If the matrix is not removed, the nail will re-form, often in a deformed and irritating manner. A second incision completes the ellipse by removing a portion of the fold of skin at the nail margin. *Center*, Cross section of area to be excised. *Right*, Loose suture of the wound, with site for drainage in the midportion.

Some surgeons prefer to excise only the lateral fourth of the nail with the nail bed and matrix, and obtain a satisfactory result. Suturing the wound is not necessary. (From Orr: Operations of General Surgery.)

it generally is necessary to excise the prominent head of the proximal phalanx to shorten the toe and allow it to be straightened. The skin and the dorsal expansion of the extensor tendon which cover the dorsum of the joint are divided through a dorsilateral incision and retracted medially. Thus the joint is opened widely, and, after division of the lateral ligament and further flexion of the middle phalanx, the head of the first phalanx can be dislocated into the wound and excised. When pes cavus and equinus are the cause of the deformity, elongation of the Achilles tendon and transplantation of the extensor digitorum longus tendons may be indicated.

METATARSALGIA (MORTON'S DISEASE). The painful affection of the metatarsophalangeal joints, probably caused by a collapse of that part of the transverse arch formed by the heads of the metatarsals, is known as metatarsalgia, or Morton's disease. Treatment is based upon the assumption that the falling of the arch brings pressure upon the plantar nerves passing forward between the metatarsal heads to the toes. Relief is afforded by supporting the arch with a pad placed beneath and just proximal to the metatarsal heads. Exercises designed to strengthen the foot muscles are instituted. When this condition does not respond to conservative treatment, surgical excision of the plantar nerve between the heads of the metatarsals should be carried out.

DISLOCATION OF THE TOES. *Dislocation of the great toe dorsally* at the metatarsophalangeal joint is a common injury from direct violence, and often is an open injury. The same difficulty may be experienced in reducing it as is encountered in the reduction of a similar lesion in the thumb: the head of the metatarsal may be caught in the fibrous tissues of the capsule or between the two heads of the flexor hallucis brevis, each of which has a sesamoid bone. In reduction the great toe should be hyperflexed into an exaggeration of the dislocation deformity, and, at the same time, the base of the phalanx must be pushed forward until it slips over the large metatarsal head. If one of the heads of the short flexor has slipped between the phalanx and the metatarsal head, the detachment of the muscle head from the base of the first phalanx is necessary before replacement can be effected.

Dislocation of the other toes, caused by jumping from a height, is common. The proximal phalanx is usually displaced upon the metatarsal, and the symptoms may be those of a sprain, but the head of the projecting metatarsal can be felt in the sole, and the toes are shortened. The space between them and the adjacent toes is increased. Diagnosis is not always easy, and is established best by the roentgenogram. Reduction is difficult and is hard to maintain.

INGROWING TOENAIL. This condition is confined to the great toe, because it alone lies flat and parallel to the plantar surface. The other toes rest upon their extremities. In the great

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